NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. IV. March, 1890. No. 3.

This Association, as a Body, is not responsible for statements or opinions of any of its members.

JANUARY MEETING.

YOUNG'S HOTEL, BOSTON, Jan. 8, 1890.

President Brackett occupied the chair at the January meeting, which was held at Young's Hotel, Boston, January 8. The following-named gentlemen were in attendance: —

Solon M. Allis, Superintendent, Malden, Mass.
R. W. Bagnall, Superintendent, Plymouth, Mass.
Dexter Brackett, Superintendent, Boston, Mass.
Geo. F. Chace, Superintendent, Taunton, Mass.
R. C. P. Coggeshall, Superintendent, New Bedford, Mass.
F. H. Crandall, Superintendent, Burlington, Vt.
Lucas Cushing, Assistant Superintendent, Boston, Mass.
Edwin Darling, Superintendent, Pawtucket, R.I.
Nathaniel Dennett, Superintendent, Somerville, Mass.
F. F. Forbes, Superintendent, Brookline, Mass.
Frank L. Fuller, Civil Engineer, Boston, Mass.
John A. Gould, Jr., Assistant City Engineer, Boston, Mass.
E. H. Gowing, Civil Engineer, Reading, Mass.
J. C. Haskell, Superintendent, Lynn, Mass.
L. E. Hawes, Civil Engineer, Boston, Mass.
Wm. M. Hawes, Commissioner, Fall River, Mass.
Geo. A. Kimball, Civil Engineer, Boston, Mass.
W. F. Learned, Assistant City Engineer, Boston, Mass.
Hiram Nevons, Superintendent, Cambridge, Mass.
Geo. J. Ries, Superintendent, East Weymouth, Mass.
W. H. Richards, Superintendent, New London, Conn.
A. H. Salisbury, Superintendent, Lawrence, Mass.
Geo. A. Stacy, Superintendent, Marlboro', Mass.
L. A. Taylor, Civil Engineer, Boston, Mass.
D. N. Tower, Superintendent, Cohasset, Mass.
C. K. Walker, Superintendent, Manchester, N.H.

F. W. Wilder, Treasurer, Woodstock, Vt.
Geo. E. Winslow, Superintendent, Waltham, Mass.
E. T. Wiswall, Commissioner, Newton, Mass.
M. F. Wright, Superintendent, Lowell, Mass.
E. R. Jones, Boston, Mass.
Prof. T. M. Drown, Massachusetts Institute Technology.
D. J. White, Clerk Common Council, Pawtucket, R.I.
Z. R. Forbes, Assistant Superintendent, Brookline, Mass.
J. G. Dennett, Pumping Engineer, Salem, Mass.
Edward Sweeney, Commissioner, Marlboro', Mass.
Chas. W. Holyoke, Commissioner, Marlboro', Mass.
Wm. G. Goldthwait, Commissioner, Marblehead.
A. P. Barrett, Water Registrar, Woburn, Mass.
P. F. Crilly, Superintendent, Woburn, Mass.
A. W. Worthley, American Frost Meter Company, Boston, Mass.
J. M. Betton, Henry R. Worthington, Boston, Mass.
B. F. Brodrick, Chadwick Lead Works, Boston, Mass.
A. W. Deane, Deane Steam Pump Company, Holyoke, Mass.
H. A. Gorham, Gilchrist & Gorham, Boston, Mass.
Albert S. Glover and H. D. Minton, Hersey Meter Co., South Boston.
H. F. Jenks, Fall River, Mass.
C. H. Baldwin, National Meter Company, New York.
F. P. Stevens, Peet Valve Company, Boston, Mass.
C. E. Roberts, Hartford Steam Boiler Inspection and Insurance Co., Boston.
J. P. K. Otis, Union Meter Company, Worcester.
B. F. Polsey, Walworth Manufacturing Company, Boston.
E. L. Abbott, Water Waste Prevention Company, New York.
J. P. Blossom, Whittier Machine Company, Boston.
Charles H. Eglee, Contracter, Flushing, N.Y.

After dinner had been served the meeting was called to order by the President, and the Secretary presented the following names of candidates for election to membership: —

RESIDENT ACTIVE MEMBERSHIP.

Lewis M. Bancroft, Chairman Water Commission, Reading, Mass.
Walter Hale, Civil Engineer, Westfield, Conn.
Arthur F. Salmon, Member Water Board, Lowell, Mass.
F. P. Webster, Superintendent Water Works, Lake Village, N.H.
Philip J. Doherty, Member Water Board, Boston, Mass.
Charles E. Drake, Civil Engineer, New Bedford, Mass.
Z. R. Forbes, Assistant Superintendent Water Works, Brookline, Mass.

ASSOCIATE MEMBERSHIP.

Wilmer Reed, Agent McNeal Pipe and Iron Co., Burlington, N.J.

On motion of Mr. Hawes, the Secretary was authorized to cast the ballot of the Association for the applicants, which he did, and the President declared them elected members.

The following papers were read and discussed by the Association: —

"Notes on Laying a 20-inch Main," W. H. Richards, New London.
"Water Supply at the Boston Fire of Nov. 28, 1889," Dexter Brackett.
"Stealing Water," G. A. Kimball.
"Laying of a 10-inch Pipe in Leicester, Mass.," F. L. Fuller.
"Effect of Water-hammer in Cement Pipes," G. L. Winslow.

The papers were discussed by Messrs. Jones, Hawes, Fuller, Darling, Tidd, Gowing, Stacy, Walker, Barrett, Nevons, Allis, Crilly, and Haskell, after which the Association adjourned, to meet on February 12.

NOTE. — The above papers and discussion will be printed in a future number of the Journal.

SOME NEW EXPERIMENTS AND PRACTICAL TABLES RELATING TO FIRE STREAMS.

BY

JOHN R. FREEMAN, Hydraulic Engineer.

Presented at the meeting of the New England Water Works Association, Boston, December 11, 1889.

A little more than two months ago I presented to the American Society of Civil Engineers an account of an extended series of experiments upon Fire Streams. Your President and Secretary have requested me to present this matter to your attention at this time by reason of the peculiar interest which recent events give to the subject of fire protection, and from a belief that to you, as the gentlemen who supply the water which the fireman uses, the practical tables accompanying the original paper would have value. I would refer any of you who may happen to desire full and complete knowledge of the means by which these tables were derived, to the "Transactions of the American Society of Civil Engineers" for November, 1889, as that memoir, and not this address, is intended to be the scientific record.

Within the past fifteen days the value of ten million dollars has gone up in smoke within ten miles of the spot where we meet to-day. As an eye-witness to these fires I have seen abundant proof of the importance of the scientific study of water supply in its relation to fire protection.

In the ordinary average year the destruction by fire in the United States alone is upward of one hundred million dollars; and in the United States alone it is estimated that twenty-five million dollars are spent in maintaining fire departments.

It is the furnishing of water for fire purposes which measures the capacity of your pumps and pipes and gives them their severest test.

Thus there need be no apology for the subject to which attention is directed at this, our first dinner of the winter, and I trust you may not find the flow of water in hose a dry subject.

In this large gathering I see so many new faces that I am tempted to follow the advice of the eloquent Motley, who said that when an unknown author presents his views upon an important theme he should begin by stating who he is.

Some of you, gentlemen, have had occasion to know me as one who vigorously holds that water-meters on a pipe supplying automatic sprinklers are a device of the devil; others among you recognize in me a man who sometimes suddenly opens a dozen hydrant streams at some mill-yard, just to see what your water works are good for, or to demonstrate to a mill manager that his boast of their excellence is a delusion and a snare, and so stirs things up that that end of the town gets muddy water for a few days.

Still others of you know me as an engineer who tries to combat the false doctrine held in some "back towns," that forty pounds is a "fire pressure," or the more prevalent error that a six-inch pipe a mile long will supply half a dozen good fire streams, or may have heard me advocate the doctrine that the man who lays a long four-inch pipe for a hydrant main ought to be banished from the land of combustible architecture.

To the others among you I beg to say that by education and profession and love for the work, I am a hydraulic engineer, and at present hold the position of engineer to an association of insurance companies.

In one small corner of the broad field of hydraulics I have tried to rear a modest structure resting on a secure foundation and fairly well finished throughout, and in building this structure I have earnestly tried to avoid using second-hand lumber.

I had for some time previously regularly used in my practice the tables of Geo. A. Ellis, a member of this society, and was also familiar with the published results of the experiments of another engineer, well known to you, Mr. E. B. Weston, of Providence.

One should speak well of the old bridge that has oft served his convenience, and the thanks of the craft are still due Mr. Ellis for the eminently practical and convenient form to which he reduced his results.[1]

When it was attempted to apply the Ellis Fire Stream tables to exact and accurate work there was trouble, for the discharge by these tables differed from plunger displacement more than could be attributed to "loss of action" in the pump.

And as to loss of pressure by friction in rubber hose, these tables gave but one value for the loss in a given length under a given discharge through common 2½-inch fire hose, thus implying that the conducting power of all kinds was practically alike. Yet, from examining different samples, it was evident that the differences in smoothness of waterway and differences in actual diameter must make the friction loss very different in different kinds of hose, and the exact kind which happened to be experimented on by Ellis was not known.

Turning to Weston's experiments, his results, except for the 1-inch smooth nozzle, were left in a form somewhat unhandy for ordinary use, being stated

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For unlined linen hose, of which thousands of feet are sold yearly to be used in certain dry indoor places, for which, if honestly made, it is the best kind of all, there were no experiments on record anywhere.

I was therefore earnest and anxious for more light on this subject, and on my presenting the matter to the association of underwriters known as the Associated Factory Mutual Insurance Companies of New England, they provided the funds to meet the very considerable expense required for apparatus and assistant observers.

The subjects investigated were: —

First. Gallons per minute discharged under various pressures by nozzles of about 40 different shapes and sizes.

Second. Loss of pressure by friction in fire-hose of various degrees of smoothness and under various different velocities of flow.

Third. Effect of curves and crooks in the line of fire-hose upon loss of pressure.

Fourth. Effect of reduction of area of waterway at couplings upon loss of pressure in hose.

Fifth. Height and distance reached by jets of water under various pressures and from nozzles of various size.

Sixth. Difference between height or distance of extreme drops as measured at a firemen's muster and the height as a good practical fire stream.

Seventh. Comparative efficiency of ring nozzle *vs.* smooth nozzle, and of other kinds.

Eighth. Distribution of velocity in jets, or comparative swiftness of current at various points in the cross-section of jet as it issues from nozzles.

Finally. Practical tables were computed covering the range of sizes commonly used.

The experiments were made at the Washington Mills, Lawrence, and through the kind influence of your member, Mr. Hunt Salisbury, the city generously coöperated in permitting the free use of the excellent public water supply.

A full technical description of the details of the experiments is given in the Transactions of the American Society of Civil Engineers for November, 1889, which paper most of you would find very dry and tedious reading. You, gentlemen, are of an eminently practical turn, and will, I think, be interested chiefly in the practical results; but that you may have confidence in these results, I must give a brief description of the means taken to insure accuracy.

The experiments were made about a year and a quarter ago. The field-work occupied about two months, and the computation and reduction of the notes into practical form occupied most of my evenings from August to May.

In this large gathering I see so many new faces that I am tempted to follow the advice of the eloquent Motley, who said that when an unknown author presents his views upon an important theme he should begin by stating who he is.

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Pressure Gauges.

In measuring pressures, for most practical purposes the ordinary Bourdon gauge is a very convenient, satisfactory instrument; but if one wishes to measure pressures and do very accurate scientific work in which it shall be absolutely certain that the gauge error is not one or two pounds to the hundred, then the ordinary forms of Bourdon gauge and even the expensive "test-gauges" are somewhat uncertain.

They are subject to unaccountable little variations, coming no doubt from the liability of the curved tubular spring to "take a set," and from the way an exceedingly minute change of form is exaggerated and multiplied by their levers and gears.

I therefore designed two light and portable open mercury columns, each about twenty feet tall and registering up to about 120 lbs. pressure, and used these in all the more important determinations. On these a difference of one-hundredth of a pound was distinguishable, and a tenth of a pound was indicated with positive certainty.

Measuring-Tanks.

To measure the number of gallons of water flowing per minute I had a square or rather oblong tank holding 1,450 gallons constructed of plank, timbered it heavily enough so it could not spring perceptibly, and then lined this with sheet-zinc, with the joints all soldered perfectly tight. I had means of measuring the depth in this tank to about the one-hundredth part of an inch. We measured the time of filling the tank by a stop-watch read to tenths of a second (though probably not really sure of this time much closer than a quarter of a second), and taking all things into account it appeared impossible for any measurement of the gallons per minute flowing to be more than a half of one per cent. in error.

Piezometers.

The next point was to attach the pressure-gauge to the hose or to the base of the play-pipe or nozzle so as to measure the exact pressure with accuracy.

This might appear the simplest thing in the world; and so it is, if one goes to work the right way. If one is working for accuracy, great care must be given to the proper arrangement of this "piezometer," as it is commonly called by engineers, and which means simply the pressure-gauge orifice in the wall of the pipe or hose.

If it were attempted to connect the gauge (as I have seen done) to a piece of $\frac{1}{8}$-inch pipe tapped into the side of the main pipe and projecting a little into the pipe, the current flowing past this projecting end would, if the current were swift as that in a fire-hose, cause such a sucking effect as to make the gauge read one or two pounds too low.

For accurate results our piezometric hole must have its edges exactly flush with the inside surface of the conduit or pipe, and without the slightest projecting roughness or burr; it must be drilled exactly square to the axis of the pipe, and the direction of the current must be parallel to the wall in which this piezometric hole is drilled.

So simple does this whole matter seem, that many of you will be surprised to learn that some of the most eminent hydraulic engineers have seriously ques-

tioned whether it were really possible to measure the pressure with great accuracy through a hole thus drilled in the side of a pipe, and will be surprised, perhaps, to learn that one of the most skilful hydraulicians of the time, Mr. Hiram F. Mills, of Lawrence, spent several months' time and quite a good many hundred dollars in investigating and settling this very point, and determining just what conditions were necessary to insure accuracy. I was an assistant to Mr. Mills at the time these experiments were made, some fifteen years ago, and by reason of the knowledge there gained gave much care to my piezometers, and for these experiments designed some of the form shown below.

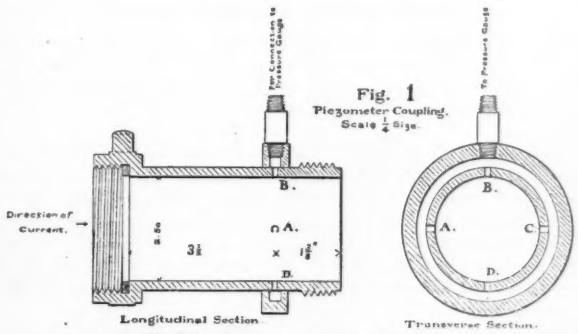


Fig. 1
Piezometer Coupling.
Scale ¼ Size.

A. B. C. D. - Piezometer Orifices. Both screw ends fit Standard hose couplings so this may be introduced at any joint in a line of hose or at base of play pipe, coupling thus forming part of the line.

FIG. 1.

You will notice that there are four holes in the side of the pipe, all communicating with the hollow ring surrounding its outside. The object of so many of these was to obtain the true average pressure, if, as is sometimes the case with a swift velocity and a pipe not absolutely straight, the current happened to set a little harder against one side than the other.

The next step in the road toward accuracy is to be absolutely sure that the rubber tube or pipe, if more than a few inches long, leading from the piezometer to the gauge is filled with water and is absolutely free from air or bubbles, as these lighten the water column and make the gauge read too high. Therefore the connecting-tube should all the way run on a slope up toward the gauge; and a cock must be provided close to the gauge, which, being opened before the experiment, will allow the water pressure to drive out the air.

I have mentioned these items with some fulness, since I am addressing a body of men who often like to do a little hydraulic experimenting on their own account, and because we have whole rafts of experiments floating down the records of hydraulics which are next to worthless as data, because such precautions have not been observed.

The Source of the Water Supply.

In addition to the city pressure, which at this point is about 75 lbs. and very free from fluctuation, we had the mill fire-pumps at command, and could thus raise the pressure to 130 lbs. As the air-chamber on these pumps did not insure quite so steady a pressure as was desired, I extemporized a gigantic air-chamber by drawing off the water from the fire-pipes throughout the mill, which is a very large one (about fourteen acres of floor), and after these were filled with air connected them with the pump-pipe; and we had no trouble from small pipes at this mill yard, for I had planned them myself some years before, and the yard main was 16 inches in diameter.

Quantity Discharged by Nozzles.

So much for some of the means and appliances, now for the experiments.

The first which may claim our attention are those to determine the gallons per minute discharged by a nozzle of a given size under various pressures.

The general arrangement of the apparatus is shown in Figs. 3, 4, 5, and 6, on opposite page.

The piezometer (Fig. 1), which I have already described, was screwed between the base of a play-pipe and the end of the hose, and the water pressure at that point thus measured by means of the mercury gauge. The jet pointed upward as in practice, and after the stream had got into a condition of steady, regular flow the jet was caught by a hood and let fall into the measuring-tank. One observer read the pressure-gauge each half-minute; another worked the stop-watch, and measured the depth in the tank; and another manipulated the nozzle and regulated the pressure.

We experimented in all upon nearly forty different nozzles, — smooth nozzles, ring nozzles, plain nozzles, fancy nozzles, and of size varying from a $\frac{3}{4}$-inch up to a Siamese nozzle of $2\frac{1}{2}$ inches in diameter. The experiments, besides yielding a rule or formula by which the delivery of almost any nozzle of a given diameter can be accurately computed, and by the aid of which the discharges in the tables presented at the end of this article are computed, also yielded the following interesting points: —

The first point of interest was that it was proved in such a manner as to leave no room for doubt that the *Ellis tables are seriously in error* in their estimate of discharge, and that the actual discharge of any ordinary smooth nozzle is about $18\frac{3}{4}$ per cent. greater than stated in the Ellis tables. For ring nozzles the Ellis tables were also found to be seriously in error; the true discharge being about $15\frac{1}{2}$ per cent. greater than given by Ellis. It may be stated also that Mr. Weston's experiments on nozzles give results agreeing well with those obtained by me, and also disproving those of Ellis, and that records of certain results by earlier experimenters also are at variance with the Ellis tables. This unaccountable error in Ellis' work is greatly to be regretted, since, owing to their convenient form, his results have been copied and reproduced into numerous trade catalogues and hand-books.

The second point of interest was that *a ring nozzle of ordinary form* with shoulders $\frac{1}{16}$ to $\frac{1}{8}$-inch deep *discharges only about three-fourths as much water* as a smooth nozzle of the same size. Any one may illustrate this readily in a rough way to his own satisfaction by calipering the stream from a ring nozzle close to

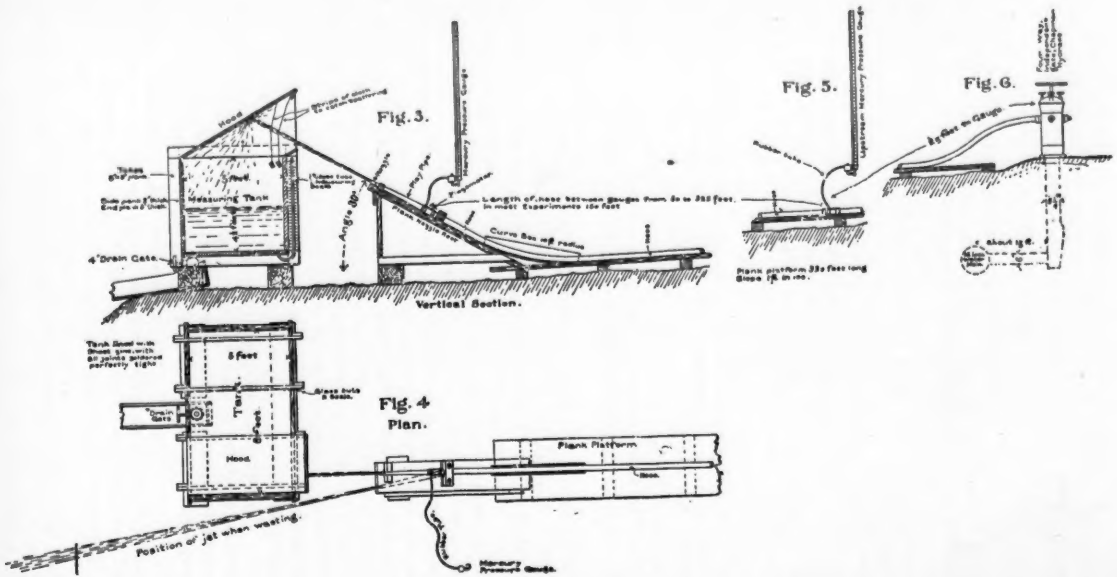


Fig. 3.
Vertical Section.
Fig. 4
Plan.
Fig. 5.
Fig. 6.
Measuring Tank
4" Drain Gate
Plank Platform
Position of jet when weighing.

FIGS. 3, 4, 5, 6.

the outlet. The jet from 1½-inch ring will be found only about one inch in diameter, or of approximately ¾ of its area.

Third. The general hydraulic law that *the discharge of a nozzle is in proportion to the square of the pressure* was found to apply with great exactness. In other words, the coefficient of discharge was found constant for the different pressures within the range of experiments.

Fourth. For measuring water under high pressures *the nozzle furnishes a means of measurement fully as accurate, and even more accurate, than the weir,* providing the pressure is measured close to base of play-pipe by an accurate gauge attached to a suitable piezometer like that shown in Fig. 1.

This was proved by the general agreement in the relation of the theoretical discharge to the actual discharge (or coefficient of discharge, as we call it in hydraulics), in experiments upon fifteen or twenty different smooth nozzles.

It was also proved by experimenting with six different 1½-inch smooth nozzles in which the diameter of the orifice was practically identical, but which nozzles were of different forms of convergence and of different shapes on the inside, and which, moreover, having been made in different shops and by different workmen, had their waterways polished out with somewhat different degrees of skill and smoothness. If any of you have a special interest in this matter, you will find the experiments recorded in detail in the paper as published in the Transactions of the American Society of Civil Engineers, Nov., 1889.

For these different nozzles it was found that under a pressure of 30 lbs., and again with a pressure of 40 lbs., at base of play-pipe, the difference from the least to the greatest, in their rates or coefficients of discharge, was less than three-fourths of one per cent.

In other words, it was, I think, proved beyond question that having by good experiments determined that the coefficient of discharge for a smooth nozzle of an ordinary good form like that which I have here, and which is shown in Fig. 21, is, say, 0.977, we can rely with certainty on the fact that for any other smooth nozzle of exactly this same size of outlet and of somewhere near the same shape, the discharge for any given pressure will be the same within a half of one per cent.

Now, a half of one per cent. is exceedingly close work in a hydraulic measurement, and it is to be understood that this degree of accuracy is to be warranted only when the pressure measurement, the arrangement of piezometer, and the calipering of the diameter of the nozzle are all done with the greatest care.

Some books on hydraulics recommend the use of a sharp square-edged orifice as a means of gauging the flow of water. The edges of such an orifice are never absolutely square and sharp, and if diameters happen to be not more than one or two inches, the slight rounding of this corner makes the measurement of the effective diameter uncertain to a degree which may easily introduce errors of one per cent. in the computed discharge. In this regard the nozzle is practically far superior to this in accuracy, since, if well made, its diameter can readily be calipered with certainty to the thousandth of an inch.

The Nozzle as a Water Meter.

For general purposes of measuring great volumes the weir must ever remain the standard method, but for measurements of smaller volumes under high pressure, the nozzle as a gauging instrument has, I believe, a high value.

To avoid possible misapprehension I would distinctly say that the tables at the end of this paper are not designed for this *extremely accurate* gauging, but are arranged rather for the quick and handy use of the water-works superintendent or of the insurance inspector, and would say, that for this extremely accurate work the pressure must always be measured close to the nozzle.

A committee of the American Society of Mechanical Engineers has under consideration the question of a standard method for pumping-engine tests. The difficulty and expense of providing a weir at many places where direct pumping is done has led one prominent member of this committee to advocate the occasional use of the pump itself as a water meter, making corrections for clearance and slip, and length of stroke.

To me it seems this is liable to be too uncertain in an important test, and I would therefore suggest the nozzle.

I am at present making preparations for some tests on certain small pumping-engines, and have under construction a new pattern of Siamese nozzle which, although intended to be as good as the best for throwing a 1¾ to a 2½ inch fire stream, is also especially adapted for use in measuring water. I had hoped to have this here to exhibit to you to-day, but from Fig. 2 you will see how handy is its application.

I would remark, however, that this sketch was made before the apparatus itself was built, and that the apparatus is less unwieldy than the sketch (Fig. 2) might imply. The barrel is of 3¾ inches internal diameter.

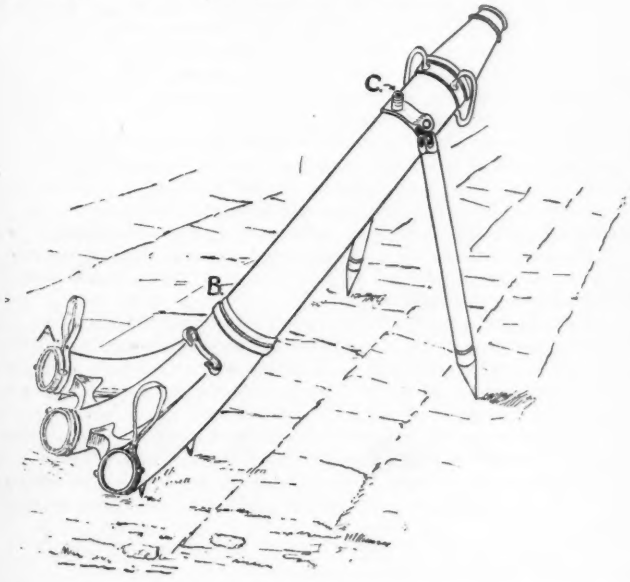


FIG. 2.

The peculiarity of this Siamese nozzle lies in the great care taken to so shape the waterways where the three streams unite and bend upward, that no whirls or eddies shall be produced in the current of water.

First. The bends upward are circular arcs carefully made tangent to the axis of the play-pipe,—and made plane curves, avoiding even the slightest warping or corkscrew-like twist, lest the water current be thereby set rotating.

Second. The cylindrical cross-section of the waterway of each of the three branches was carefully merged into V-shaped section where the branches united near B, thus preserving a thin partition of metal between each, so the currents do not unite until the straight single pipe is reached at B.

Third. The area of each waterway was carefully and gradually reduced as the branches came together going toward B, so that the water moves about 15 per cent. faster at B than at A. This gradual convergence tends to prevent eddies in the water at the concave side of the bend.

Fourth. Hollow cross-connections between the three branches at A were formed in the casting, so that in case one line of hose happened to be delivering more water than the others, the currents would, under the influence of the diminished area at B, tend to equalize, and thus give a more uniformly distributed current in pipe approaching the nozzle.

Fifth. To further reduce the liability to twisting of the currents, a thin 3-way "rifle blade," so called, extends from B for 16 in. toward C, this being set so that the blades halve the current from each of the three branches. At C is a hollow ring covering four orifices, and thus forming a piezometer on the same principle as that shown in Fig. 1. The ends at A are each fitted with an ordinary hose-coupling. Claws on the bottom of Siamese prevent its kicking back, and two light movable props, which can instantly be folded up out of the way and held in the spring-hooks alongside the barrel, serve to conveniently support it at any convenient angle, as shown.

This, all complete, will not weigh more than 75 pounds, and except for the pattern-work, which absorbed a good deal of time, by reason of the care taken in trying to give the curves and junction an almost mathematical exactness of form, would probably cost less than $100, exclusive of the pressure-gauge. One man can carry it easily from place to place, can set it up all ready for use in ten minutes, and yet it will, I think, prove equal to the gauging of a flow of 1,400 gallons per minute, or at the rate of 2,000,000 gallons per 24 hours, with an accuracy and certainty not excelled by the best-arranged weir.

All the setting-up required is to connect three lines[1] of good, new rubber-lined hose into it, and all the change or fittings required about the pump would be simply to attach some hose-valves to its force main. A table or a diagram of discharges for each pound of pressure can be prepared easily, so nothing will be necessary but to read the gauge and refer to the table for the gallons per minute.

A larger apparatus on the same plan could of course be made to take more lines of hose and measure the capacity of a larger pump, or a number of the smaller ones could be used.

I shall test this, and will let you know how practical use proves it. I have already done some experimenting with a less perfect apparatus, or I might not be so sanguine about this new one. It strikes me there are some other purposes about water works for which this simple, accurate, and portable water meter of great capacity would be useful, such as testing a pipe line for obstruction, or for measuring the volume that the distribution system could supply at a given point in the city without reducing the pressure below a given point. Moreover, a contrivance of this size, or larger, would be handy for the engineman to have at hand to test his pump with from time to time to see if the "slip" were becoming too large.

[1] I expect that it will also serve to take care of the water from four lines of hose, by connecting a common 2-way Siamese into the middle branch.

For a "duty trial" where large interests are at stake a mercury pressure-gauge would be most exact and satisfactory. Still, the Bourdon gauge will measure the water-pressure here as well as it will the steam-pressure, and will even do it better, or, in fact, about twice as well, for 2 per cent. error in the nozzle-pressure will cause only about 1 per cent. error in the discharge.

A good Bourdon duplex spring gauge, if compared and rated before and after the test by the beautifully simple and accurate (if properly used) gauge-tester made by the Crosby Gage & Valve Co. will answer almost every practical purpose.

The Venturi meter of Herschel will doubtless prove a very valuable instrument for the same class of work, of measuring large volumes under pressure, or for a permanent apparatus; but for temporary use in cases where the escape of the water is allowable the nozzle will, I think, unquestionably prove the cheaper and simpler, and give a little more precision of measurement.

As I said above, this very handy apparatus, while capable of serving for the most accurate kind of a meter, is also adapted for use as a piece of heavy artillery by the fire department; and the care taken in shaping its waterway, where the three streams merge into one, gives a freedom from eddies and twists and cross-currents in the nozzle which will, I trust, make it shoot a considerably more clean and solid jet than that ordinarily obtained from a Siamese nozzle.

Loss of Pressure by Friction in Fire-Hose.

This is the next point of interest connected with the experiments. This friction loss was determined for fourteen different kinds of 2½-inch hose. These were intended to represent all the typical kinds of hose in ordinary use, but no attempt was made to experiment upon all the different makes, sizes, and brands in the market, — these being so very numerous. The tests embraced leather hose, solid rubber hose, unlined linen hose, and rubber-lined hose of various kinds. Not only was 2½-inch hose tested, but some experiments were made with hose of 2 inches and 2¼ inches in diameter. A surprising difference was found in the conducting power of the different kinds of hose.

The hydrant-pressures in the different experiments varied from 15 to 125 pounds per square inch, and the delivery of the hose from about 50 to 325 gallons per minute. We thus had velocities of flow ranging all the way from 3 to 21 feet per second.

The details of the experiments are fully described in the Transactions of the American Society of Civil Engineers, to which I have already referred, and extended tables are there given showing the gauge reading, the lengths, the delivery, and the friction loss for 124 different experiments. It is hardly worth while to go into details here, but I will try to give, briefly as may be, the general results of the experiments.

General Arrangement of the Apparatus.

The effort was made useless in all respects to reproduce practical conditions as nearly as possible. The hose was connected to a Chapman hydrant at its up-stream end, and nozzles of first one size and then another, varying all the way from three-quarters of an inch up to one and three-quarters inches in diameter, were attached to the down-stream end. The hose rested upon a uniformly sloping

plank platform about 350 feet in length, and the length of hose at one time under experiment varied anywhere from 50 to 325 feet. Although 325 feet was the greatest length used in any case, the results of the experiments are entirely applicable to any length however great, even up to half a mile, as the friction loss determined for 100 feet would be substantially the same for any other 100 feet of the same hose under the same conditions. It may be stated that experiments made first with a line of hose 300 feet long, then 150 feet, then 100 feet, and then 50 feet of the same hose, showed that the loss was, as might be supposed, strictly proportional to the length of the hose; in other words, with any given number of gallons per minute flowing, the loss of pressure in a line of hose 300 feet long was found to be almost exactly three times as much as the loss of pressure in a piece 100 feet long.

The pressures within the hose at various points were measured by means of mercury gauges and the piezometers already mentioned; the piezometers being coupled into the line between two sections of the hose at any desired point. Although the pressure directly at the hydrant was noted in many of the experiments, yet the up-stream piezometer and pressure-gauge from which friction loss was computed were generally located 25 feet down-stream from the hydrant, in order to get the pressure at a point far enough away from the hydrant to be certain that the current had got into a regular condition of steady flow. The measurement of the number of gallons of water discharged per minute was for those pressures, as well as for those on nozzles, made in the tank already described.

Care was taken to support the rubber tubing which connected the piezometer with the pressure-gauge so it should be on an even slope upward toward the gauge, in order that air-bubbles might not lodge and affect the results. Moreover, just before and after each set of experiments a waste-cock connected directly to the gauge was opened for a moment, so that the swift current through this small tube should effectually wash out any possible bubbles. The cocks between the gauge and the piezometer were generally kept wide open during an experiment, for I believe that small errors are often introduced by the too close throttling of a gauge to check oscillations, as often practised.

If there happens to be a minute leak between the gauge and the point throttled, then the gauge may be made to read much too low (in these experiments we took good care that there were no such leaks); or if it so happens that the water flows through the orifice in the cock or diaphragm more readily in one direction than in the other, then as the waves or oscillations occur the gauge reads a little too high or a little too low, according to the direction in which the flow happens to be easier.[1]

We had a straight line painted along the plank platform, mentioned above, and stretched our hose out empty along this straight line. On letting the water into the hose, hose of almost every kind expands somewhat in length. For some kind of hose, a piece 100 feet long when empty will be 105 feet long when full of

[1] It sometimes happens when the passage or the cock leading to a gauge is so closely throttled that a minute speck of dirt may lodge just above this small aperture and act like a check-valve, and if there is much oscillation gives a fictitious reading which is much too high.

A form of minute, leaky check-valve is sometimes applied to hydraulic gauges intended to measure high pressure, as a means of checking an injuriously rapid fall of the gauge; such a device may lead to very erroneous results if there happens to be much oscillation.

water under a pressure of 50 pounds. The result of this elongation is to throw the hose into a serpentine form.

We had three observers — one at each of the pressure-gauges — who observed these gauges each half-minute for the whole duration of an experiment, and one at the measuring-tank. Another assistant managed the turning of the water into or out from the tank, and as we were timing this to tenths of seconds it had to be sharply and quickly done. This was very easily arranged for, as illustrated in Fig. 4. By a very slight deflection of the nozzle to one side the water passed outside of the hood and wasted into the river beyond, and the throwing the jet across the sharp edge of this hood required but an almost inappreciable length of time. As each experiment on friction loss was computed from the average of five to ten independent observations taken simultaneously at the two ends of that length of the hose under experiment, I feel confident that the error in determination of the pressure lost by friction in going from one end to the other of any given sample did not exceed one-half pound, and in general it was much less than this.

Fig. 8 shows the general results of the experiments for as many kinds as could have their curves plotted on this sheet without leading to confusion, and Table No. 1 gives the comparative result of each of the different kinds of hose under experiment. The heliotype illustration (Fig. 7) brings out the reason for the difference in friction loss in various samples in a striking manner.

TABLE No. 1.—COMPARATIVE FRICTION LOSS IN VARIOUS KINDS OF FIRE HOSE. The following comparison is made on the basis of 240 gallons per minute, flowing through hose in each case, which is about the quantity discharged by a 1⅛-inch smooth nozzle under a pressure of 40 lbs. (indicated) at base of play pipe.

SAMPLE OF HOSE.	Diameter of couplings. Inches.	Average internal diameter of hose. Inches.	Mean velocity in hose. Feet per sec.	Increase in length under 50 lbs. average pressure.	Observed loss of pressure due friction in each 100 ft. of hose. Hose straightened and length measured under pressure. Lbs. per sq. in.	Percentage corresponding to diam. of hose to be added or subtracted to give friction which would have existed had diam. been exactly 2½ inches.	Loss of pressure due friction in each 100 ft. of hose, which this same hose would have shown had diam. been exactly 2½ inches. Lbs. per sq. in.
Sample A. **2 1-2 in. Solid Rubber Hose. Boston Woven Hose Co.'s "Extra."** A heavier hose than the next, weighing 25% more. The interior of this hose is free from ridges due threads of fabric, and was intended to be smooth as rubber could be made; being made on a highly polished steel mandrel.	2.52	**2.65**	13.96	¾%	**10.0**	**Add 34%**	**13.4**
Sample B. **2 1-2 in. Solid Rubber Hose. B. W. H. Co.'s "Volunteer."** The interior of this hose is free from ridges due threads of fabric, and very smooth, but was made on a mandrel less highly polished than the last.	2.53	**2.60**	14.50	1½%	**11.5**	**Add 22%**	**14.0**
Sample C. **2 1-2 in. Woven Cotton, Rubber-Lined. B. W. H. Co's "Boston Fire Jacket Hose."** A Regular heavy Fire Department Hose. Rubber lining is thick, and interstices between threads next to rubber lining filled with rubber, so that inner surface remains almost free of ridges under pressure. Hose of same grade as Sample D with addition of a jacket. (See Photograph.)	2.53	**2.47**	16.07	4%	**15.0**	**Deduct 6%**	**14.1**
Sample D. **2 1-2 in. Woven Cotton, Rubber-Lined. B. W. H. Co.'s "O. K. Hose."** A medium-weight unjacketed hose. Rubber lining thicker than Sample K, and interstices between threads next to lining filled with rubber, so that inner surface remains almost free of ridges under pressure. Smoothness and character of lining apparently the same as Sample C. (See Photograph.)	2.47	**2.49**	15.81	5%	**14.5**	**Deduct 2%**	**14.2**
Sample E. **2 1-2 in. Knit Cotton, Rubber-Lined. N. Y. B. & P. Co.'s "Cable No. 2 Hose."** A medium-weight hose. Inner surface medium smooth under pressure. Interstices between threads next lining well filled wth rubber. (See Photograph.)	2.50	**2.68**	13.65	3½%	**11.3**	**Add 42%**	**16.0**
Sample F. **2 1-2 in. Knit Cotton, Rubber-Lined. N. Y. B. & P. Co.'s "Dart Hose."** A cheap, light-weight hose. Interior surface medium smooth.	2.50	**2.50**	15.69	4½%	**16.8**	**0**	**16.8**
Sample G. **2 1-2 in. Knit Cotton, Rubber-Lined. Callahan's "Jacket Hose."** A regular Fire Department Hose. Said to be about the same grade as Sample I with a jacket added.	2.51	**2.60**	14.50	1¾%	**13.9**	**Add 22%**	**17.0**
Sample H. **2 1-2 in. Knit Cotton, Rubber-Lined.**							

A regular Fire Department Hose. Said to be about the same grade as Sample I with a jacket added.	2.51	2.60	14.50	1¾%	13.9	Add 22%	17.0
Sample H. 2 1-2 in. Knit Cotton, Rubber-Lined. Callahan's "Mill Hose." A rather cheap, light-weight hose. Inside rather rough, due conformation of rubber lining to threads of fabric.	2.51	2.62	14.28	3%	14.4	Add 27%	18.3
Sample I. 2 1-2 in. Knit Cotton Rubber-Lined. Callahan's "Volunteer Hose." A somewhat heavier hose than the last, otherwise apparently the same. (See Photograph.)	2.51	2.69	13.55	2½%	13.5	Add 44%	19.4
Sample J. 2 1-2 in. Leather Hose. S. Eastman & Co.'s "Improved." A leather hose of excellent construction. Laps cut square.	2.50	2.80	12.51	2¼%	12.2	Add 76%	21.5
Sample K. 2 1-2 in. Woven Cotton, Rubber-Lined. B. W. H. Co's "Mill Hose." A cheap hose with medium-thin rubber lining, which under pressure conformed to threads of fabric, thus making interior full of small ridges. (See Photograph.) I infer from comparative appearance of roughness that most other makes of woven "Mill Hose" of same weight would as now made give similar friction, but that they can be improved as illustrated in Sample D.	2.48	2.53	15.31	5%	24.1	Add 6%	25.5*
Sample L. 2 1-2 in. Unlined Linen Hose. This was an excellent piece of hose, made by Ross & Turner, and fairly represents friction loss in all ordinary unlined linen hose. (See Photograph.)	2.50	2.60	14.50	2½%	27.2	Add 22%	33.2
Sample M. 2 in. Woven Cotton, Rubber-Lined Hose. Smoothness apparently same as sample D, as judged by inspection of interior at ends of sample.	2.07	2.12	21.81	4½%	33.2	Deduct 56%	14.6
Sample N. 2 in. 1-4 in. Linen Hose with 2 in. Couplings. Fabric same as Sample L. (Value deduced from experiments with 200 gallons per minute flowing in this hose.)	1.95	2.30	18.53		49.5	Deduct 34%	32.7
For comparison with above, it may be stated that the loss of pressure due friction in a common, clean, straight wrought-iron pipe coated with tar or asphaltum, and 2½ inches diameter, discharging 240 gallons per minute would be, computing and interpolating from experiments of Hamilton Smith, Jr., 15.7 lbs. per 100 feet } mean							14.8
" " " " " " Henry Darcy, 14.0 " " " " " }							

The correction given in the sixth column is based upon the well-known hydraulic rule, that for the same quantity flowing in long pipes of different diameters, but equal smoothness, the friction loss is in inverse proportion to the fifth power of the diameter.

The truth of this rule within the limits of the above experiments is demonstrated very well by a comparison of the last two experiments on samples **M** and **N**, with experiments on samples **C** and **L**.

The figures in the seventh column give the true basis for judging of the relative excellence of a hose as regards smoothness of finish of interior.

*In justice to the Boston Woven Hose Co., the writer desires to state, that since learning the result of these experiments, they have been experimenting and modifying process of manufacture so that interior of mill hose shall retain a smooth surface even under heavy water pressure.

Influence of Smoothness of Surface of Waterway upon Loss of Pressure in Hose.

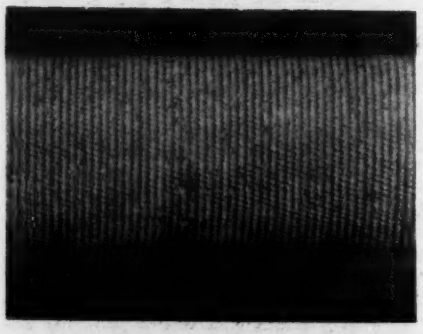
One of the most interesting and valuable points illustrated by these experiments was the very great effect which the smoothness of the inside of hose exerts upon the amount of pressure lost by friction. To determine the exact degree of roughness when the hose was subjected to water-pressure, plaster casts were made of the interior of samples cut from the various kinds. These plaster casts were made by taking a sample from the hose about three feet in length, holding this in a vertical position, and filling it with plaster of Paris, and then instantly screwing on a cap, through which it was connected to a hydrant with a pressure of 50 pounds per square inch. After the plaster had hardened the hose was cut off, leaving the cast as shown in Fig. 7. It was found that casts from some samples of hose were very preceptibly more rough or corrugated than was the hose itself when not subjected to pressure; this being due, of course, to the forcing out of the rubber lining against the threads of the fabric when under pressure.

Much Fire-Hose is Wastefully and Needlessly Rough.

As to the influence of roughness on friction loss, compare sample K with sample C (Fig. 7). Each was a hose of woven cotton fabric, of medium weight, lined with rubber; both were made by the same manufacturer, and were practically alike, with the exception that K was rough on the inside, while C was smooth. Sample K was made, as most "mill hose" and a great part of the "fire department hose" is ordinarily made, namely, with a rather thin rubber lining, which was in calendering permanently roughened by the twill of the cloth used, and which was further roughened and corrugated by its conformation to the threads of the fabric, and still further corrugated when in use, by the rubber lining being forced by the water-pressure into the crevices between the threads, thus giving a surface, as shown by the photograph of the cast K (Fig. 7), which contained corrugations projecting a little more than $\frac{1}{64}$ of an inch.

Sample C and sample D were made by the same maker and of the same material as K, but were made with more care, and the loss of pressure by friction in the hose was found to be but little more than half as great as in the rougher hose. Their rubber lining was calendered smoothly, and was slightly thicker than in sample K, and means were adopted for filling the crevices between the two so that the rubber lining should be well backed up and its inner surface not forced into a corrugated form by the action of the water-pressure. This filling of the crevices between the threads may be attained either by the free use of suitable rubber cement, applied with proper apparatus, or by inserting the rubber lining into the cotton fabric in a semi-plastic partially vulcanized condition, and then completing the vulcanization under such conditions as to permit the rubber before hardening to flow slightly, and thus fill the crevices between the threads.

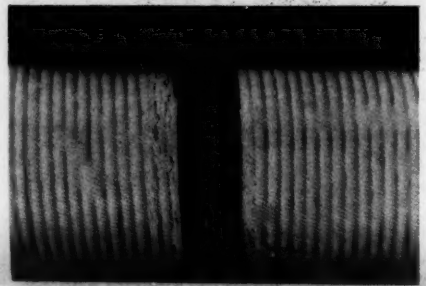
Careful weaving of the hose is also essential if one would obtain smoothness, and consequent low friction loss, for sample E was apparently as smooth as C, except for a waviness of surface, produced apparently by unequal tension



The figures for Linen Hose in tables pages 136 to 167 were based on experiments upon this sample.

SAMPLE L. **UNLINED LINEN HOSE.**

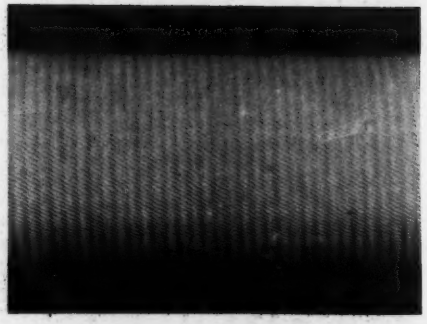
33.2 lbs. pressure lost by friction per 100 feet in length (or 2½ times as much loss as in sample C, shown below).



This sample served as basis for the values for "Inferior Rubber-lined cotton hose, inside rough," quoted in tables pages 136 to 167.

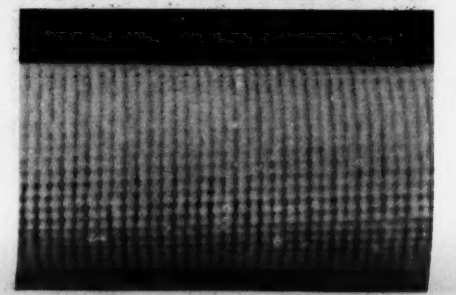
SAMPLE K. WOVEN COTTON, RUBBER-LINED, "MILL HOSE."

25.5 lbs. pressure lost by friction per 100 feet in length of hose (or



SAMPLE X. Not tested for friction. Cast taken to illustrate unnecessary roughness, often caused in process of manufacture.

Fabric and Lining same as C, except that twilled cloth was used in calendering face of rubber lining, thus roughening surface.



SAM[illegible] HOSE.

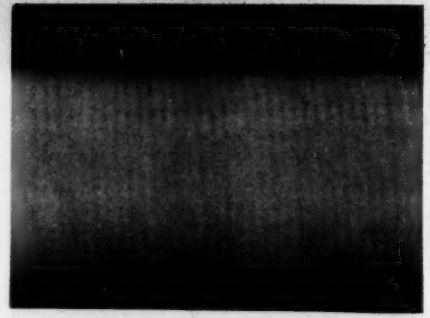
Average height of roundabout ridges about [illegible] inch.

quoted in tables pages 136 to 167.

SAMPLE K. "WOVEN [illegible] RUBBER-LINED HOSE."

25.5 lbs. pressure lost by friction per 100 feet in length of hose (or 80 per cent more loss than in sample D and C, shown below).

Rubber lining was rather thin, and crevices between threads next lining not being well filled, the water pressure caused inner surface to conform to threads of fabric.



This sample served as basis for values for "Ordinary best quality Rubber-lined cotton hose, inside smooth," given in tables pages 136 to 167

SAMPLE C. **WOVEN COTTON, RUBBER-LINED HOSE.**

(Average depth of corrugations, $\frac{1}{1000}$ to $\frac{2}{1000}$ inch.)

14.1 lbs. pressure lost by friction per 100 feet.

Rubber lining slightly thicker than in sample K, and interstices between threads next lining well filled with rubber, so inner surface remained smooth under pressure.

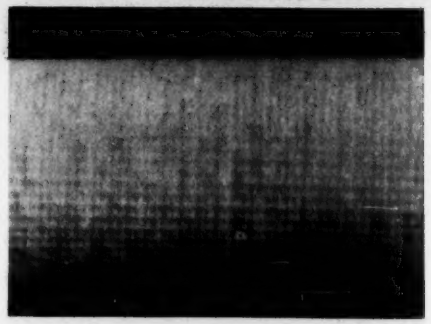
SAMPLE D had same kind of Rubber lining, and gave loss of 14.2 lbs. per 100 feet.

SAMPLE [illegible] HOSE.

Average height of roundabout ridges, about $\frac{1}{250}$ inch.

Average height of ridges which run lengthwise about $\frac{1}{1000}$ inch.

19.4 lbs. pressure lost by friction per 100 feet in length (or 37 per cent more friction loss than in sample C).



SAMPLE E. **KNIT COTTON, RUBBER-LINED HOSE.**

Interstices between threads next lining well filled.

16.0 lbs. pressure lost by friction per 100 feet in length (or 13 per cent more friction loss than in sample C).

PHOTOGRAPHS FROM PLASTER CASTS OF INTERIOR OF FIRE HOSE.

Casts were all taken under a pressure of 50 lbs. per square inch. Photographs are half size of originals.

Losses of pressure given above are those found for 240 gallons per minute (or a good 1¼-inch fire stream) flowing in hose exactly 2½ inches in diameter.

FORBES LITH. MFG. CO.

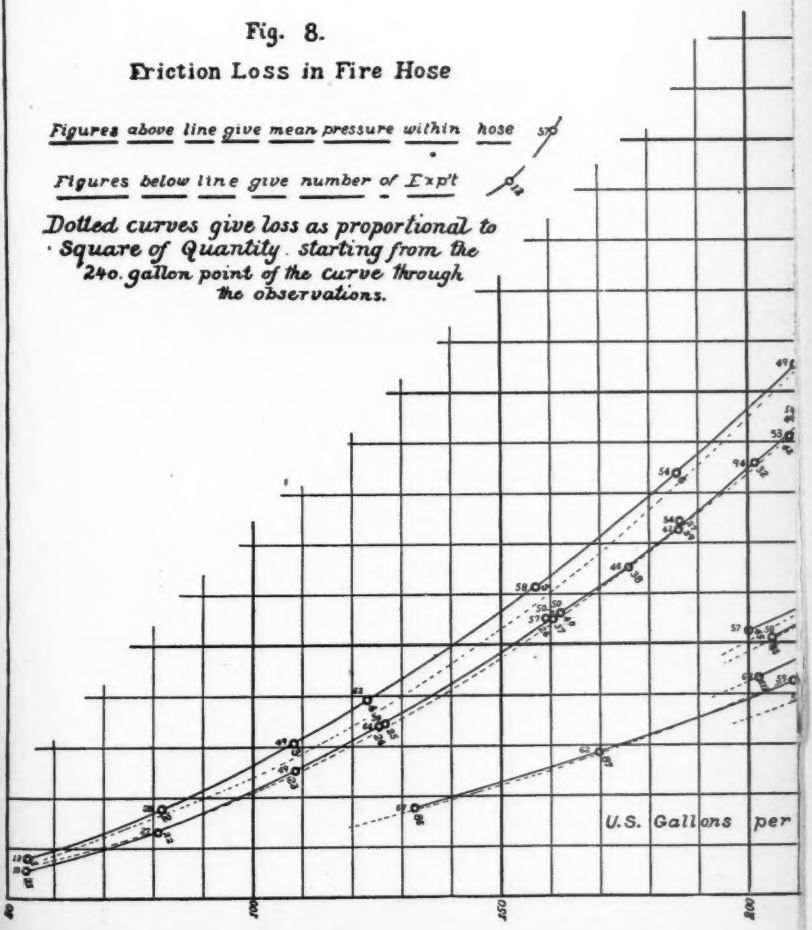
Fig. 8.

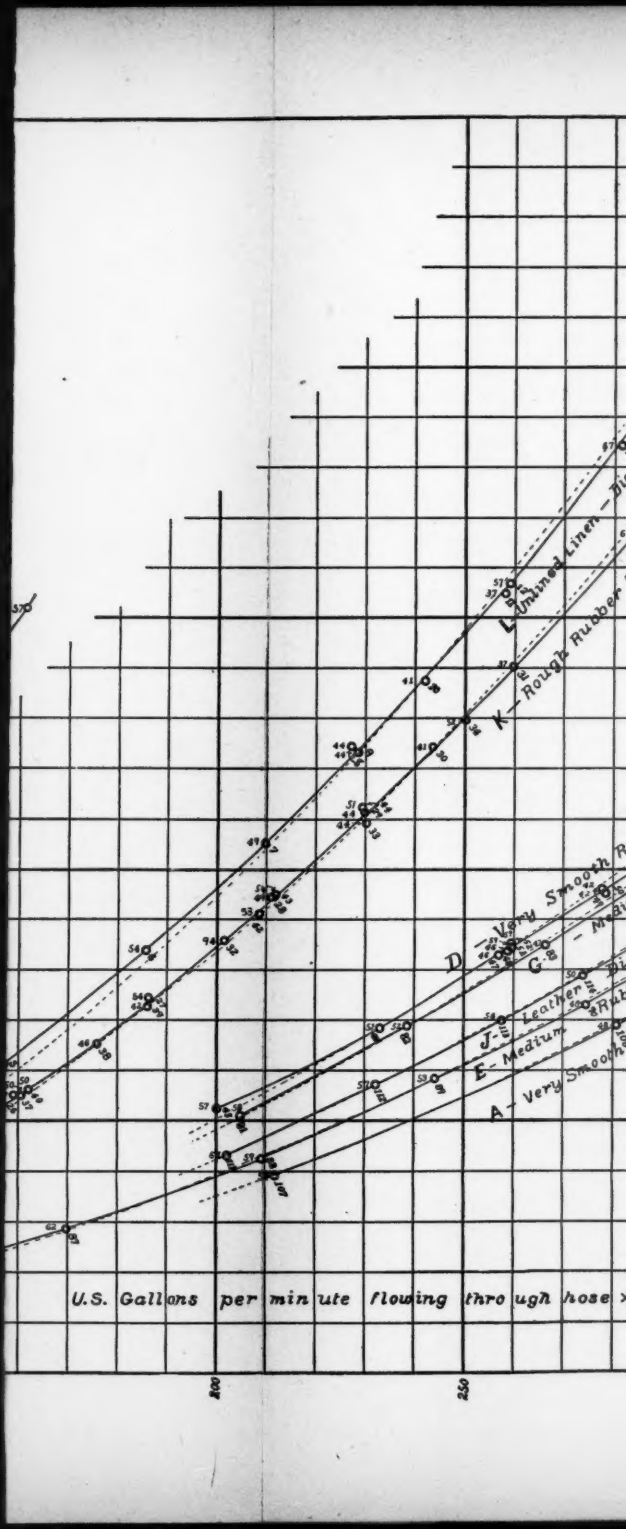
Friction Loss in Fire Hose

Figures above line give mean pressure within hose 57

Figures below line give number of Exp't 14

Dotted curves give loss as proportional to Square of Quantity, starting from the 240. gallon point of the curve through the observations.




L - Unlined Linen - Ru
K - Rough Rubber
D - Very Smooth R
G - Medi
J - Leather
E - Medium
A - Very Smooth
U.S. Gallons per minute flowing through hose
200
250

Rough Rubber Lined – Diam. 253"
Rubber Lined – Diam. 268"
Rubber Lined – Diam. 280"
Rubber Lined – Diam. 265"
Solid Rubber Diam.
Pounds pressure lost per
100 feet of hose
50
40
30
20
10
0
300
300

in the loom. Had the loom been perfectly adjusted the friction loss would, for the same diameter, have been little, if any, greater than that in C.

Inasmuch as the loss of pressure in a line of 2½-inch hose 1,000 feet long, which is smooth like C, will be no greater than in a line 550 feet long containing such roughness as K, I would **most strongly advise fire departments when purchasing hose to specify and insist that its smoothness be fully equal to that of a good, smooth sample to be furnished before the contract is given.**

The cost of sample D, in which the friction loss was only about fourteen pounds per 100 feet, with a good 1½-inch stream, was only five cents per foot greater than sample K, in which the friction loss was about twenty-five pounds, and I am informed that with the proper arrangements at the factory the extra cost of obtaining a smothness like that of sample C is small.

This point of improving the smoothness is well worthy the attention of all hose-makers. I am led to emphasize it especially from having many times heard hose manufacturers and hose salesmen affirm positively that this little roughness of interior surface had no influence on the loss of water-pressure, that the water next the side lay dead, etc.; which notions, though conclusively proved to be erroneous, as every hydraulic engineer knows, by the experiments of the eminent French engineer, Darcy, thirty-five years ago, are still advocated as an aid to the disposal of imperfect hose.

As to the means by which such small roughness of surface are able to exert such powerful effect upon the friction loss, we may consider that the greatly increased loss is mainly due to the ability of these small projections to set the whole stream to its very centre into a condition of turmoil and minute eddies, just as a single stone at the bottom of a smooth and deep canal is sometimes seen to produce a boiling at the upper surface.

The results given in Table 1 and shown in the photograph of the casts (Fig. 7) also serve as one strong reason for discouraging the use of unlined linen hose in any situation excepting for the stand-pipes inside a building, where the lines of hose are generally short. For it is seen that the gallons per minute delivered and diameter of hose being the same, the loss of pressure by friction in each 100 feet is more than twice as great with the linen hose as with a thoroughly first-class rubber-lined hose.

Effect of Bends or Curves in Line of Hose upon Friction Loss.

This subject was investigated first by carefully measuring the friction loss in a line of hose laid with the ordinary natural sinuosity, and then, without lessening the pressure or interfering with the flow, straightening the same hose out and repeating the experiment. The mean of quite a number of trials with different kinds of hose and with bends of different sharpness was taken, and the experiments agreed fairly well in showing that six per cent. increase in friction loss was a very fair allowance for the effect of any ordinary curvatures and crookedness in which the hose was not cramped or choked off by a sharp angular bend. We might, perhaps, have expected this loss would be greater; still, it must be remembered that the ordinary curves in a line of fire-hose are of longer radius in proportion to diameter than are the longest of "long-turn" pipe-fittings.

Effect of Obstructions at the Coupling.

Throughout the United States an expanded ring-coupling which gives a waterway of the full diameter of the hose is now used by all the best makers. On old hose and on some inferior hose a shank coupling is often used which has its bore ¼ inch smaller than the diameter of the hose itself.

We therefore tried some experiments to determine the effect upon the loss of head of inserting a square-edged bushing ⅛ inch thick at each 50-foot coupling, thus getting a waterway like that in these old-style couplings. It was found that with a 240-gallon stream these increased the loss ½ pound per hundred feet.

In our regular experiments the rubber or leather washers used to make a tight joint at the coupling were all cut out to full size of the 2½-inch coupling. In practice the washers often project into the waterway. We therefore tried the effect of washers projecting in ⅛ inch, or with a 2¼-inch hole, and also tried others projecting ¼ inch, or with a 2-inch hole. The increased loss due these small washers, as deduced from these experiments, is given below.

Effect of Small Washers in Hose-Couplings of 2½-inch Bore.

Diameter of hole in washer.	Increased loss of pressure per 100 feet, or for two washers.		
	200 gallons per minute flowing.	240 gallons per minute flowing.	300 gallons per minute flowing.
2⅜-inch.	0.20 lbs. per sq. in.	0.30 lbs.	0.46 lbs.
2¼	1.04	1.50	2.34
2⅛	2.32	3.34	5.22
2	4.16	5.98	9.34

Influence of Diameter of Hose upon Loss of Pressure by Friction.

The exceedingly great influence of even small differences in diameter upon the friction loss attendant on forcing any fixed number of gallons per minute through a line of hose or small pipe is not generally appreciated. The friction loss varies as the fifth power of the diameter, as engineers express it, and thus if a sample of hose happens to be 2⅜ instead of 2½ inch, *this ⅛ inch difference in diameter is sufficient to make twenty-five per cent. difference in the loss of pressure by friction.*

Now, 2½-inch hose is not all just 2½ inches in diameter. The samples of "2½-inch" upon which I experimented varied all the way from about $2\frac{7}{16}$ to 2¾ inches.

Moreover, while under pressure a "woven" hose expands in length, but not in diameter. A knit hose expands not much in length, but chiefly in diameter, and to the extent of about $\frac{1}{16}$ inch for each 50 pounds pressure.

The most convenient way for measuring diameter of inside is to caliper the outside under pressure and mark the spot; then empty the hose, squeeze it together flat between some blocks by some screw-clamps, and thus caliper the thickness of material, which, being deducted from the outside diameter, gives the inside diameter.

Shall the Standard Diameter of Fire-Hose be Changed?

As stated above, the very great difference which a small change in diameter of hose makes upon the loss of pressure due to a given flow is not generally appreciated. For any definite number of gallons per minute flowing, **the loss of pressure is only 40 per cent. as much in a 3-inch hose as it is in a hose exactly 2½ inches in diameter.** For a hose 2⅞ inches in diameter the loss of pressure is just half as much as in a 2½-inch hose; and if we go down to small sizes and make use, as is often done in the protection of factories and of some villages, of hose only 2 inches in diameter, *the loss of pressure in this 2-inch hose is three times as great as it is in a 2½ inch hose.*

That this great difference, although seldom appreciated, is no less a fact, is not only proved by theory, but I have more than once had occasion to demonstrate it experimentally when urging a mill manager to discard his 2-inch hose and refit his premises with hose of larger size. By way of illustrating the principal bearing of this question of the effect of small differences in diameter upon the flow, we might say that if the Boston Woven Hose Co., for instance, should slightly change the diameter of the "two and one-half inch" hose designated as sample C in Table No. 1, increasing it only by $\frac{3}{16}$ of an inch, so it would be of the same size as was the sample of "two and one-half inch hose" marked E, then the loss of pressure per 100 feet of its length would be nearly one-third part less than at present, the smoothness being the same in each case; and as a further illustration, we may say that if some enterprising fire company earnestly desired the prize for distance-playing at a fireman's muster, and would procure some hose 2¾ inches in diameter (if this were like sample D, without a jacket, the difference in apparent size would be so slight that it could hardly be detected), then, with a line of hose 300 feet in length, as is common in such trials, this increase in the waterway would give them a far greater advantage than would any style of fancy nozzle, and would, in fact, send the extreme drops about 20 feet farther.

From strong practical reasons this slightly increasing the diameter of such brands of woven cotton rubber-lined hose as are now made exactly 2½ inches is well worthy of consideration. The bore of the coupling could continue 2½ inches, as at present; and even though the hose were, as a regular thing, made 2¾ inches in diameter, the loss from this smaller size of coupling, coming as it does only once in 50 feet, would be almost unappreciable, providing the reduction from 2¾ to 2½ inches were made gradual, on a taper, with corner at end of taper smoothly rounded off, instead of by a square-cornered shoulder. This can easily be provided for, especially by increasing length of coupling a little, and not add more than 25 cents to the cost of the couplings.

The present size of fire-hose was established many years ago, in the days of the old hand-engines, or before steam fire-engines had attained their present perfection and power. This was also before the Portland fire, the Boston fire, the Chicago fire, and numerous extensive factory fires had given costly object-lessons as to the value of large-sized streams. For a wooden dwelling, or for a fire in an ordinary small-sized store, or for any fire in its incipiency, — in fact, for nineteen out of twenty of the fires to which the department of the ordinary city responds in the course of a year, — a jet from even a ¾-inch nozzle may be

large enough; but once let a fire get under full headway, and the demand for something larger is imperative.

The water from a small stream falling in the condition of finely divided spray is evaporated and turned into steam almost before reaching the fire, while a 1¼-inch jet from a smooth nozzle in the first place sprays less, and, in the second place, contains a sufficient volume of water, so that even though half be evaporated in the flames, there is a body left which can go through the burning gases and strike the coals themselves.

A fire is never put out by playing into the flames. It is only put out by cooling off the burning coals themselves by the bodily application of water to their surfaces; yet this simple and fundamental fact appears to be not nearly so widely understood as it should be.

I have been an eye-witness of quite a number of very extensive fires, and each time I have been struck with the general feebleness of a large proportion of the streams, and conversely I have seen many instances to prove that a fire must be an exceedingly hot one when a good, stiff, clean 1¼-inch jet, fairly delivered in its midst, will not leave a black mark. Occasionally, of course, fires obtain such headway in undivided structures of large area that even a stream of this size is evaporated; but I have studied this matter carefully as an eye-witness in instances enough to convince me that the reason we so often hear that the streams proved unavailing, is that a thoroughly first-class, large-sized stream is so comparatively rare; and with the ordinary range of water-pressure at steamer it is useless to think of playing a stiff 1¼-inch stream [1] through more than 500 feet of fire-hose of average smoothness, as generally made to-day, so long as diameter is not greater than 2½ inches. (As already stated, some few makers now make their so-called 2½-inch hose actually almost 2¾ inches in diameter, and gain greatly in the saving of friction.)

The 2¾-inch hose mentioned above, fitted with couplings of 2½-inch bore and the present screw, so as to be absolutely interchangeable, would, with the same pressure at the hydrant or steamer, give a stream at the end of 1,000 feet of hose equally as large and strong as can be obtained from a line of hose just 2½ inches in diameter and only 650 feet long.

As I said above, the present hose will answer well enough for nineteen fires out of twenty, and perhaps for even a larger proportion, but when a fire of great magnitude occurs, ordinary hose and nozzles are not at all suited to cope with it, mainly by reason of the great loss of pressure between the engine and the nozzle.

The only possible objections to this larger hose are, first, the increased weight to handle. This cannot be considered insurmountable in view of the fact that some of the knit hose already in use is, when expanded by pressure, of nearly 2¾ inches in size, and is handled without difficulty. Moreover, a length or two of light unjacketed 2½-inch hose could be used next the nozzle for inside work or work upon ladders, for my proposition is that all the hose, large and small, have interchangeable couplings. The second objection is the reduced bursting strength due to the larger diameter. This, with the fabric remaining just the same, would amount to only ten per cent., and any fabric now testing at 500 pounds on a 2½-inch diameter would stand 450 pounds on a 2¾-inch. In fact, the

[1] Forty or fifty lbs. nozzle-pressure.

best 2½-inch jacketed fabrics of to-day are amply strong enough to stand a 3-inch diameter. In general, however, the saving in pressure lost by friction would enable the working pressure at engine to be less, and thus make a saving in working strain, offsetting the weakening by increased diameter. I incline very strongly to the opinion that it will be found best not to rest content with a 2¾-inch diameter, but to go far enough, while we are about it, and adopt a 3-inch diameter as the standard for fire-hose.

Still, until practical experience has been had in the manipulation of this hose, and until it is proved with certainty that it is not too large and cumbersome for regular use, I would adhere to the interchangeable coupling with the standard thread and of 2½-inch bore.

There is no greater evil than getting lots of hose into a fire department which are not perfectly interchangeable. A computation which I have made shows that with these couplings of 2½-inch waterway, located 50 feet apart, and with their bore ½ inch less than diameter of hose, the loss of pressure due to the small area of these couplings *would offset only one-twentieth part of the gain coming from the larger size of the 3-inch hose*, providing, as already stated, the reduction in the diameter of the coupling at the screw from 3 inch to 2½ inches was made with a taper, and not with a sharp, square shoulder.

This advantage of 3-inch hose is not wholly a matter of theory. I am told that it has been reduced to practice with the most gratifying results. Over a year ago I presented the facts, much as I have just presented them, to the treasurer of the Eureka Fire Hose Company, of New York. I am pleased to say that the Eureka Company have taken action in this matter, and have furnished several thousand feet of such hose to various fire departments, and I am told that it is not found too heavy to handle, and that its operation is in every way gratifying.

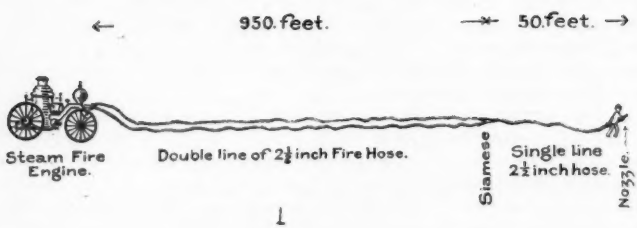
I am well aware that the National Association of Fire Engineers considered this matter at their last meeting and decided adversely to it, but I feel that this decision must have been reached without a proper understanding and consideration of all the facts in the case. I have considered the whole matter in the light of these experiments, — considered it as I went around "within the lines" at the fierce and rapid fire which burned the Lowell Railroad storehouse, and considered it again as I went from point to point in the heat of the fire at Lynn a fortnight ago, and I am still just as confident as ever of the merits of the proposed change.

With this 3-inch hose a 1¼-inch stream can be played at the end of a line 1,200 feet long just as powerful as can now be played with the same engine-pressure at the end of a line 500 feet long. And a stiff 1½-inch stream with lines of moderate length from a first-class steamer would involve no great difficulty.

Double Lines of Hose for Long Distances.

While we are on this subject I may also add a word to the effect that at many fires which I have attended it is almost agonizing to see the ignorance displayed by the engine captains as to the friction loss in hose. It is also a matter of great regret to see how seldom a Siamese coupling is used to connect two lines of hose *from one steamer* into a single line at a point 50 or 100 feet back from the nozzle, in cases where the distance from the steamer to the seat of the fire is great.

Fig. 24.



I refer now not to the use made of the Siamese for connecting the water thrown by two steamers into a single large and powerful stream, but rather to its use in reducing the friction loss between any one steamer and the one nozzle which it is supplying. When we thus carry the water through *two lines* of hose instead of through a single line of hose, the velocity of the water is, of course, but *half as great* in each of the two lines. The result of this is that the *loss of pressure is only one-fourth as much* as in the first case, and if the steamer stands 1,000 feet away from the Siamese, we have by the double line of hose practically reduced this distance to 250 feet. This is fact as well as theory, as you can readily demonstrate by trying the simple experiment for yourselves.

Or if, for convenience of working, the Siamese is placed 50 feet back from the nozzle, as shown in Fig. 24, then, although the nozzle is a thousand feet from the steamer, the loss by friction is so lessened by the double line of hose that with the same steamer-pressure a jet will be thrown with exactly the same force as though steamer were only 287 feet from a nozzle on a single line of hose.[1]

At other fires I have seen two steam fire-engines laboring heavily to do what one steamer and a double line of hose could have done much better.

I refer to one steamer pumping into the second steamer, and the second steamer pumping on to the fire.

There are many good practical firemen who will say it is contrary to common practice and to common sense to claim that this Siamese and the double line of hose will do more work than the second steamer; but let them try the experiment and see. We can also prove it by a simple little computation.

Suppose the fire to be 1,800 feet away from the nearest good source of water. Suppose the fire so large that we earnestly desire a good 1¼-inch stream. This requires 240 gallons per minute.

1st case. — Two steamers and a single line of hose. By Table A, No. 4, p. 143, it may be seen that to barely deliver this 240 gallons per minute through 1,000 feet of the best 2½-inch hose into the suction of the second steamer will require a water-pressure of 130 pounds at the first steamer. And the second steamer must

[1] This is proved thus: For the 950 feet of double line each stream will move with half velocity, and therefore the loss by friction will be one-quarter as great as though all this water were going through a single line of hose $\frac{950}{4} = 237$ feet. To this add the 50 feet single line, and we have 287 feet.

show a water-pressure of 145 pounds to play this good 1⅛-inch stream on the fire through 800 feet of hose and get the necessary 40 pounds pressure at the nozzle.

We thus have to tax two powerful steamers to their utmost to get a single good 1¼-inch stream on the fire.

2d case. — For the same situation take a double line of hose 1,750 feet long, bring the two together by a Siamese, and to this attach a single line of hose 50 feet long leading to the nozzle. To give our stream pressure 40 lbs. at the nozzle we must, 50 feet back from the nozzle, at the Siamese, have a pressure of 47 pounds, and thence for the 1,750 feet back to the steamer the 120 gallons per minute flowing in each branch will cause only $\frac{1}{4}^{3} = 3\frac{1}{4}$ pounds friction loss per hundred feet, or 57 pounds in all, which added to the 47 gives 104 pounds at the steamer.

In the first case, with two steamers, one playing into the other, the average steamer-pressure was 137½ pounds.

In the first case the entire labor of one steamer and one-fifth of the labor of the other are absorbed in useless friction, which is wholly avoided by the extra piece of hose. And repeating the idea in still other words, by way of still more emphasis on this overlooked but valuable point, the simple expedient of dividing the stream into two parts, and uniting them again by a Siamese a convenient distance back from the nozzle, is more efficient than an extra steamer, and sets the second steamer free for an additional stream on the fire.

At Lynn the other day I saw in one case a powerful steamer attempting to play its stream through 2,000 feet of hose.[1]

I saw another steamer trying to pump through 1,500 feet of hose, and the streams reached about as high as a small boy could propel water through a squirt-gun. Moreover, it has been my duty to investigate a number of mill fires where the department has complained of the "unaccountable failure and loss of pressure in the water supply," that "somehow it failed to give its usual force," when the only reason in the world was that whereas on dress parade they were accustomed to test with *50 or 100 feet* of hose, they were obliged in their time of danger to use more lines of hose and to play through *several hundred feet of hose.*

[1] I counted the lengths myself, and then got a friend to count them independently, and there were either forty or forty-one fifty-foot lengths.]

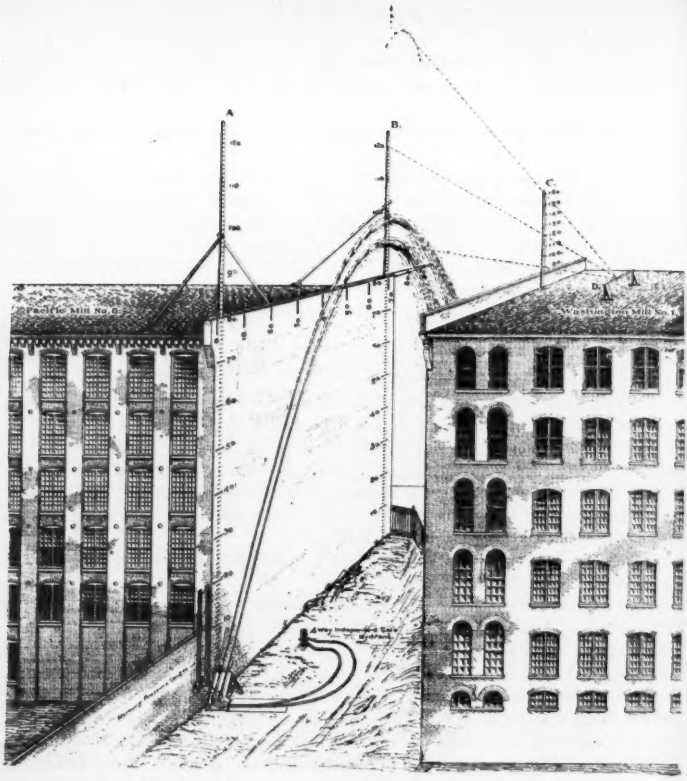


FIG. 9. — EXPERIMENTS ON FIRE STREAMS AT HIGH ELEVATIONS.

The final experiments on which tables for height of jets are based were made at this site, but in these only one nozzle was used at a time.

The above sketch illustrates experiments to determine which of two nozzles (ring or smooth, for instance) was the better, or would throw stream highest and with the least spraying, — pressure at base of each play-pipe being the same. For this the two 50-feet lines of hose leading to play-pipes were of same kind; bends in hose at base of play-pipe were carefully laid flat on the inclined platform, as shown, and clamped between blocks jig-sawed from 3-in. plank, so each hose lay in flat curve of 3 feet radius. One to two feet of hose next base of play-pipe was straight.

The masts, A and B, were graduated in feet, and reached to a height of 124 feet above nozzle. Below the masts, scales, made of strips of wood strung on heavy steel wire, marked each foot in height along face of wall.

Horizontal distances from end of nozzle were marked by wooden rods 10 feet apart, nailed to top of wall, as shown.

When height of jet was more than 130 feet, the mast, C, and sighting-bar, D, were used in estimating height, proper allowance being made for parallax.

The play-pipes and their supporting platform could be set at any angle of elevation required, and securely clamped.

End of nozzle was set level with zero of mercury pressure-gauges and zero of scale of height.

An assistant regulated pressure to within one-tenth of a pound by valves at hydrant, and, when all was ready, one observer read the mercury gauges each half-minute, while another observed and noted height and characteristics of jet, as seen from the mill roofs.

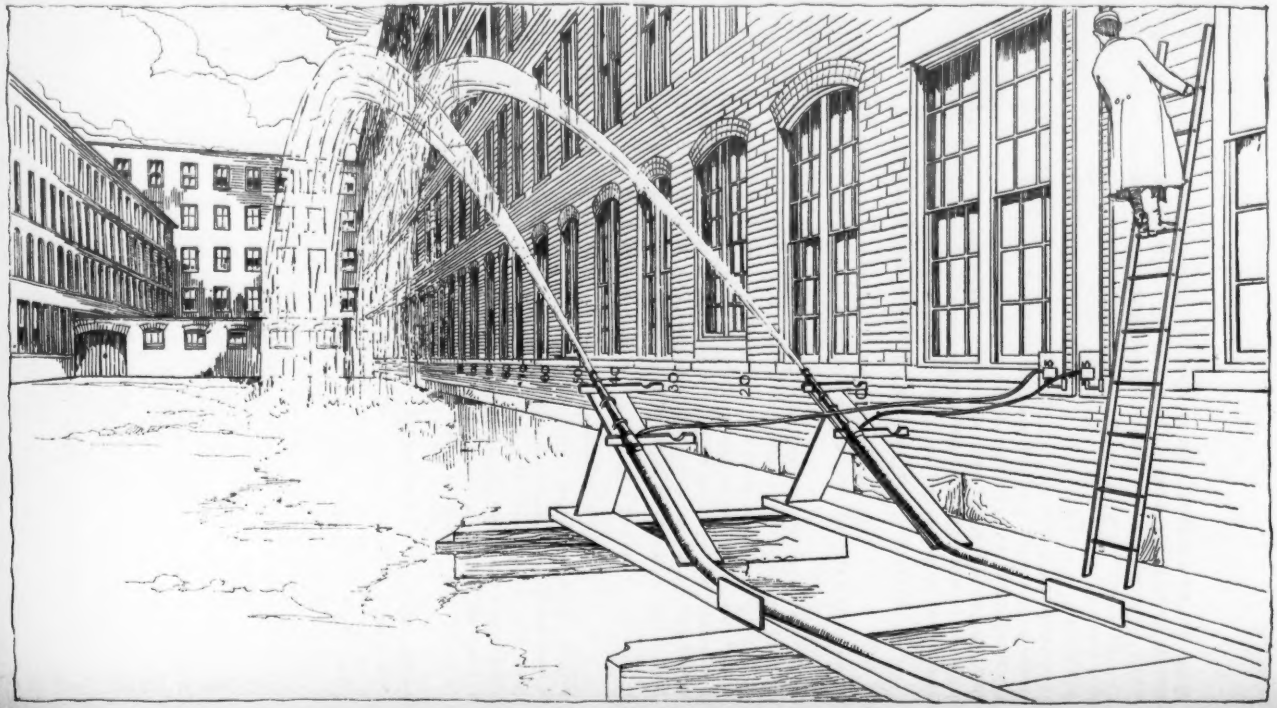


Fig. 10.

Experiments on Jets.

Fig. No. 9 and Fig. No. 10 show the general arrangement of the apparatus for the experiment on jets. It will be seen that we had unusually convenient situations for making these experiments accurate. The difficulty found was not of trouble with apparatus, but was of trouble with air currents or wind. It was very difficult to find a time when air was so still as not to influence the results. For six weeks, while engaged on other experiments here described, we kept the apparatus handy, and watched for the smoke from the neighboring chimneys to rise vertically. Several times we started in and found the effect of the wind so evident that we stopped. It was found that a moderate summer afternoon zephyr would affect the height or the reach of the extreme drops fully ten per cent., and there is no doubt whatever but that the remarkable records sometimes made at firemen's musters are due to a favoring gust of wind far more than to the perfection of their "fancy nozzle."

The detailed results are given in the paper already referred to, and so here we need only say that these experiments furnished the basis for the heights stated in the practical tables at end of paper. Not only were the previously recorded experiments on height of jets very few indeed, but they gave only the height and distance of the extreme drops. This reach of extreme drops is almost worthless information for the firemen, and as given in pump catalogues has worked deception and false sense of security to the purchaser of pumps.

Height and Distance as a Good Fire Stream.

I gave much attention and earnest effort in trying to determine the limiting distance as a good practical fire stream under the several pressures. This point is not sharply defined. It is hard and puzzling to draw the line and say to a foot or even to five feet just where the stream ceases to be good. Some experienced firemen would no doubt class it as good at a point ten per cent farther or higher than I did, but I kept the effect of a moderate wind in mind, and also took the distance at a point where the stream had not lost its continuity by breaking into a shower of spray.

The jet diagram (Fig. 10) gives this information about the height and distance reached by jets in a very practical and convenient form.

Comparative Efficiency of Various Kinds of Nozzles.

The figures Nos. 9 and 10 illustrate the conditions under which the comparisons were made so fully as to call for little further comment. The nozzles compared were tested side by side for distance, as per Fig. 10, and for height, as per Fig. 9, under conditions as nearly absolutely identical as they could be made, and I believe them to have been by far the most accurate set of comparative experiments on this subject ever made. I say this in the effort to carry conviction to the hearts of the ring-nozzle advocates.

Ring Nozzles *vs.* Smooth Nozzles.

The first point to be settled was, of course, the oft-argued question of ring nozzles *versus* smooth nozzles. These, with both "undercut ring" and "square ring," were compared in various sizes, and finally I constructed a ring nozzle

with an orifice of such size that under a given pressure it discharged the same number of gallons per minute as a 1⅛-inch smooth conical nozzle.

These tests showed in the most positive and convincing manner that either the common form or the undercut form of the *ring nozzle does not possess the slightest superiority over the smooth nozzle.* The difference between the two was, however, small, and in general amounted to about two per cent. in favor of the smooth nozzle. It may be well to stop a moment and explain to some who are not firemen just what is meant by a "ring nozzle." The following three figures make the distinction plain. The "ring nozzle" has a sharp corner or contraction close to the end, and some people suppose this cuts off or holds back the more disturbed part of the current close to the walls of play-pipe.

FIG. 11. — SMOOTH NOZZLE.

FIG. 12. — SQUARE RING.

FIG. 13. — UNDERCUT RING.

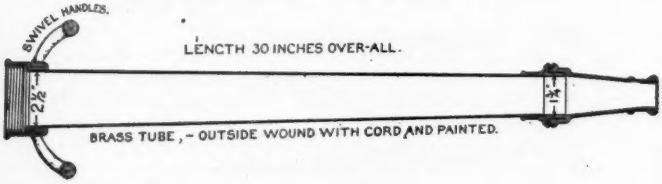
We find so many ring nozzles in use, and find their merits so stoutly maintained, that I will state that a final demonstration of the general range of these experiments, at which two of the most eminent hydraulic engineers of the time, Mr. James B. Francis and Mr. Clemens Herschel, did me the honor of their presence, and at which Mr. Salisbury, member of this society, and also the full corps of Inspectors of the Associated Mutual Insurance Companies, a body of men who in the regular course of their duties pass critical judgment upon thousands of fire-streams in the course of a year, were present. *I believe all present to have been satisfied that the ring nozzle was in no way superior to the smooth.* Examining both jets at points within a dozen feet of the nozzle, one had just as much of that mythical "surface smooth as a glass rod" as the other.

The only advantage of the ring nozzle is that it makes a show of playing a larger stream than is the fact. The ring makes the stream contract to about an eighth of an inch smaller than the size of the hose. It may afford satisfaction to the builder or the engineer of a steamer to say he is playing a 1½-inch stream, when actually throwing only as much water as will go through a 1-inch smooth nozzle; but the apparent benefit as to distance reached which sometimes actually comes from the use of a ring nozzle is easily explained, and is just the same as would be secured by using a good smooth nozzle of ½-inch smaller diameter. The gallons per minute thrown being less, the loss of pressure by friction in the hose is less, and therefore the greater pressure available at base of nozzle impels the stream a greater distance.

Not only were comparisons made with ring nozzles, but comparative tests of various other kinds of nozzles were made. The forms experimented on, and their effect and relative value, are detailed in my paper before the Civil Engineers. The whole result may be summed up by saying that *nothing was found which was in the slightest degree superior in projecting qualities to a good, plain, smooth, conical nozzle like that shown in Fig. 21.*[1] This result was contrary to

[1] The cone must converge with a good degree of taper, like Fig. 21; for on testing a conical nozzle known in the trade sometimes as a "screw nozzle" and very commonly sold, this was found about six per cent. inferior in projecting power, due to the too small waterway in throat of play-pipe, next to where the nozzle or tip screws on.

STANDARD NOZZLE FOR FACTORY USE.



DETAILS OF
Proposed Standard Nozzle.

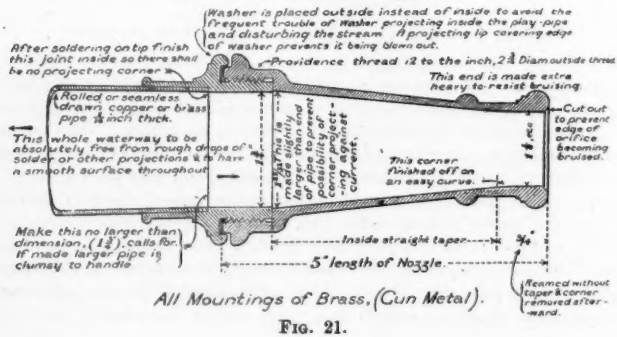

Washer is placed outside instead of inside to avoid the frequent trouble of washer projecting inside the play-pipe and disturbing the stream. A projecting lip covering edge of washer prevents it being blown out.
After soldering on tip finish this joint inside so there shall be no projecting corner.
Providence thread 12 to the inch, 2¾ Diam outside thread.
This end is made extra heavy to resist bruising.
Rolled or seamless drawn copper or brass pipe ⅛ inch thick.
Cut out to present edge of orifice becoming bruised.
This whole waterway to be absolutely free from rough drops of solder or other projections & to have a smooth surface throughout.
This is made slightly larger than end to prevent possibility of corner projecting against current.
This corner finished off on an easy curve.
Make this no larger than dimension, (1¾), calls for. If made larger pipe is clumsy to handle.
Inside straight taper.
5" length of Nozzle.
Reamed without taper & corner removed afterward.
All Mountings of Brass, (Gun Metal).

FIG. 21.

my anticipation, for I had confidently expected to find some other form that would give a more polished, smooth, solid, far-reaching stream.

I may here record that though I have looked for it a thousand times, I have never yet seen a stream issuing under a pressure higher than twenty pounds at nozzle which did have a clean, glassy, transparent surface for any considerable distance away from the nozzle. A careful and minute examination will show that under a pressure of forty pounds, even at only an inch distance from the smoothest and best nozzles, minute drops are beginning to tear themselves away from the main stream, thus giving the jet a roughened appearance like ground glass.

With a view to getting a better class of play-pipe and nozzle into general use in our mills, I designed the nozzle shown in Fig. 21 as one result of the above experiments, and furnished blue-prints of the working-drawings to about all of the leading makers of fire apparatus, so that now it is a matter of regular stock to be found with most dealers, and is known in the market as the "Underwriter pipe."

There is nothing specially novel about it, and there is no patent upon any part of it. I merely combined those elements which had been found to give the best results. Other high-grade nozzles can be found in the market or in use which will probably give just about as good results, but the experiments described above make me firm in the belief that there is nothing now made that will throw any better stream than this will, and if any of you happen to want a nozzle for accurately gauging up to 250 or 300 gallons per minute, this, in connection with a piezometer like Fig. 1 screwed into its butt-end, will fill the bill.

With firemen a flexible play-pipe tapering but little if any up to a point within a foot from the end, is at the present time more popular than a metal pipe. I tested one of these, and found that if properly made with a smooth interior, and with its cone on a smooth regular taper, it would throw very nearly as well as Fig. 21; but the Underwriter pipe was, as stated above, designed for mill use, where it may be called into play after standing twenty years, while flexible rubber or leather fabrics are liable to fail from the rotting of the rubber when no more than five years old.

I include below cuts of a few of the kinds of nozzles tried, a glance at which may be of a little interest to some of you.

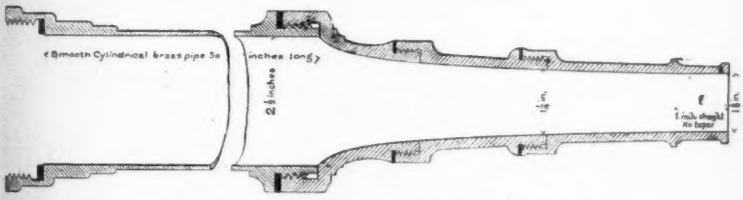


FIG. 14. — 1¼-INCH "UNIFORM ACCELERATION" NOZZLE.

It has been thought by good authorities that there was good theoretical ground for expecting the above nozzle to give superior results. Careful comparison in

the manner of Figs. 9 and 10 showed that there was no appreciable difference either in reach of jet or in amount of spraying between this nozzle and that with straight taper like Figs. 15 or 21; and thus this elaborate form was proved to have no advantage over the plain cone with straight taper.

Value of the Non-Tapering Cylindrical Part at End of Nozzle.

Nozzles of these two forms next shown were tested side by side on similar play-pipes. C was like A, except that about an inch had been cut off close to end of taper.

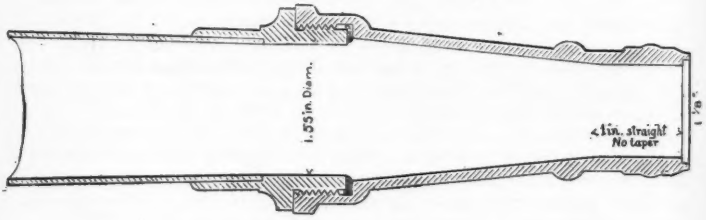


Fig. 15. — Nozzle A.

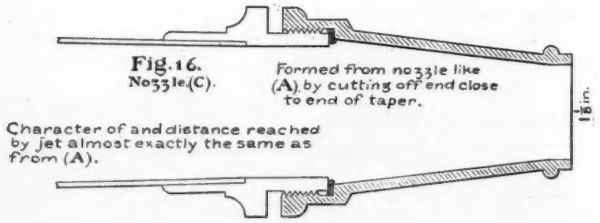


Fig. 16.
No 33 1/2 (C).
Formed from nozzle like
(A) by cutting off end close
to end of taper.
Character of and distance reached
by jet almost exactly the same as
from (A).
1 6/16 in.

There was no perceptible difference in the two jets at 50 pounds or at 100 pounds pressure, showing the cylindrical part at end of cone is not really needed.

NOZZLE WITH RADIAL BLADES FOR STRAIGHTENING CURRENT.

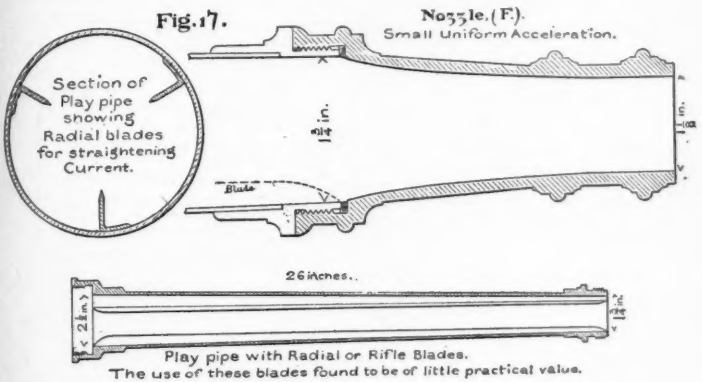


Fig. 17.
Nozzle. (F.)
Small Uniform Acceleration.
Section of Play pipe showing Radial blades for straightening Current.
Blade
26 inches.
Play pipe with Radial or Rifle Blades.
The use of these blades found to be of little practical value.

No difference between this and the plain cone could be detected, and the use of the blades was found to be of little value.

Another style of play-pipe (Silsby), in which the three radial blades extended to centre, was tried, and its blades were found to give it no advantage over the smooth cone, so long as hose lay in a plane, vertical curve. If, however, both lines of hose were put into a spiral corkscrew-like form, the jet from the plain pipe fell short two to five per cent. by reason of the twist in the water, while that from the pipe with the blades held its own. In a Siamese jet, where three lines of hose were united into one, from the play-pipe immediately up-stream, these blades, like Fig. 18, were found to aid materially by removing twisting of current and keeping stream from spraying.

FIG. 18.

The following were also included:—

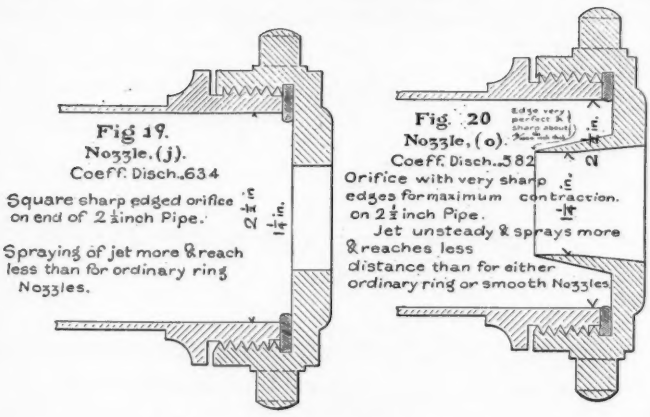


Fig 19.
Nozzle. (j).
Coeff. Disch. .634
Square sharp edged orifice on end of 2 inch Pipe.
Spraying of jet more & reach less than for ordinary ring Nozzles.
Fig. 20
Nozzle, (o).
Coeff. Disch. .582
Orifice with very sharp edges for maximum contraction. on 2½ inch Pipe.
Jet unsteady & sprays more & reaches less distance than for either ordinary ring or smooth Nozzles.

Velocity in Different Parts of Jet.

There is but one other set of experiments to which I will call your attention, and I will do this very briefly. These were upon the comparative velocity in different parts of the stream just after it left the nozzle, — or "distribution of velocity," as it is called. By a delicate instrument, on the principle known among hydraulic engineers as that of "Pitot's tube," the pressure of the current in different parts of the stream was measured, and from this the velocity computed. These are the first investigations on record of this kind with regard to jets, and you may find the results rather curious.

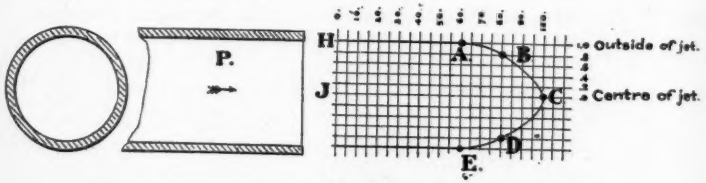


Fig. 22.

Let P be a straight, cylindrical pipe 5 feet or more long, from which the water is being discharged in a forcible jet. It was found that for a jet from a pipe like this, experimented on at a point close to the nozzle, the velocity at centre was very much the greatest, and that the velocity grew less rapidly as we approached the side. Thus, if we represent the velocity in the centre of the jet by the distance J C, then the velocity close to the side of the jet will be represented by the distance H A, and the curve, A B C D E, will represent the velocity at the different distances from the centre. Thus we found the velocity close to

the side to be only 60 per cent. as great as the velocity in the centre of jet. This, be it remembered, is for a straight, uniform pipe.

With a rapidly converging nozzle the relation was very different. Thus, for the standard conical nozzle, similar to Fig. 21, the curve of distribution of velocities was as shown below.

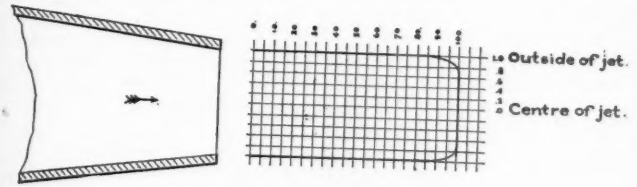


FIG. 23.

For three-quarters of the way from centre to circumference the velocity of all the fluid threads is the same, and is found to be just equal to the theoretical velocity due to the pressure. Within a short distance of outer surface of jet there is a little retardation, however, coming from the friction of the walls of the nozzle; and, by careful measurement, the total amount of this retardation near the sides is found to just equal the difference between the theoretical discharge and the actual discharge, or to fully account for the "coefficient of discharge," as we call it in hydraulics.

It was found that with the "sawed-off" nozzle (Fig. 16) this retardation was a trifle less than with the nozzle of Fig. 15, while with the sharp reëntering knife-edge of Fig. 20, the retardation at side was still a little less, but not very materially different from that found to exist for the nozzle shown in Fig. 15 or 21.

PROPER ALLOWANCE FOR A GOOD FIRE STREAM.

Before closing the subject I would like to say a few words about a question which we hear often agitated among water-works engineers and mill managers; viz., How many gallons per minute is a fair allowance for a good fire stream?

We have statements all the way from 175 gallons per minute up, and these estimates have been made in all sorts of ways, such as by attaching a meter to a hose stream, or by dividing up the water-works pump record by the number of streams supposed to have been thrown during a fire.

The point I would make is this: The needs of the present and the future should have a voice in answering this rather than the mere record of gallons thrown on certain past occasions. The problem should be attacked wholly from the two following standpoints:—

1st. What diameter of jet, within reach of one steamer and one line of hose, is practically the best?

2d. What pressure at the nozzle can the pipe-men handle to best advantage?

The argument rests wholly with these two questions. These two questions once settled, then the tables and experiments which I have presented give a complete answer.

To cite some great fire of the past, and say that the counters on the water-works pumping-engine indicated 1,750 gallons per minute while ten streams were being thrown, and therefore 175 gallons per minute is a proper allowance for a good practical fire stream, is by no means a complete answer, until it has first been shown whether these were really *good* practical fire streams.

Let us illuminate this question a little by the light of the Lynn fire. Going from point to point, I carefully looked at stream after stream. Many of them could not rise to a third-story window, or reach far enough so firemen could be safe from falling walls or sheltered from scorching heat, and still deliver water to the critical point. *Not one in four could be called a first-class fire stream. Our apparatus is planned for the ordinary fire, not for the extraordinary fire.*

Why are the streams so often feeble?

For the moment, and in your presence, we will assume that the water works are all right;[1] the steamer *is* all right; there is no trouble about getting a nozzle which is all right. *The trouble is generally in the hose*, which may be so long, so small, or so rough, that it will not carry the water so fast as the nozzle can use it, or as the steamer can furnish it.

In a great fire like that at Lynn or at Boston a 1¼-inch stream from a smooth nozzle should be the smallest used. With 30 pounds at the nozzle this will go 50 to 60 feet above the pavement in good, solid form, ready for business, and require *265 gallons per minute*. With 50 pounds at the nozzle two or three good men can still handle it easily, and it will rise at a good working angle 70 to 80 feet above the pavement, still in compact form, not a mere spray, all ready to flash into steam, — and *this calls for 347 gallons per minute*. And sometimes a 1⅜ or even a 1½ inch stream will, after we get better hose, be called into use.

Those, gentlemen, are the streams with which the fireman of the future is going to work when he has serious business in hand.

After the great Boston fire, with its cost of seventy million dollars, they added an eighth of an inch to their nozzles; and gradually, gentlemen, by object-lessons, at a cost of many thousand dollars apiece, the firemen will get educated to have such hose and their apparatus so arranged that they can instantly, if serious occasion demands, throw a good stiff 1¼-inch stream, even though steamer be 500 or 1,000 feet away from the hosemen; and you, gentlemen, have got to fix your water mains so as to give the water to do it with.

Although we should be prepared to supply any particular stream with 300 or 350 gallons, yet even at a great fire, at any given moment, some steamers will be stopped, some hosemen will be along the skirmish line at work with smaller streams, wetting down roofs and washing incipient flames off from wooden cornices and mansards; and taking all these things into account, I believe that we ought, in our computations and estimates for water supply, to provide at the very least an average of *250 gallons per minute for each stream* in the business centre of a city, or round about any extensive factory. In a dwelling-house region less will suffice.

Two hundred and fifty gallons per minute for each first-class hose-stream is

---

[1] At Lynn, in the westerly part of the burned district the steamers had plenty of water in the pipes from which they drew, but on the easterly or leeward side some of the steamers located on a slight rise of ground were sucking at almost empty pipes.

the figure which I regularly use in my estimates for designing or proportioning the pumps and pipes for the protection of large factories.

Effect of Jets of Water on Fierce Fires.

I have heard much said about water having no effect on a fierce fire. I have tried earnestly to watch its effect on some three or four fierce fires. I believe there is once in a very great while a fire which would instantly turn a 1¼-inch stream into steam as it passed through the flames (and then the 1¾-inch or the 2-inch Siamese stream may come into action with great effect, if steamers can be spared from surrounding property), but I believe the frequency of such occurrences is greatly exaggerated, and that the verdict, "The streams seemed to have no effect," comes more than nine times out of ten from the streams being feeble.

I have seen a good, stiff 1¼-inch stream make a black mark wherever it hit, on an extremely hot fire; and this tempts me once more to illustrate how simply the ordinary steamer of to-day can throw a stiff 1¼-inch stream, even though 1,000 feet away from the fire, and to again refer you to Fig. 24.

By this simple arrangement of the double line of common hose the wasted effort — the friction loss — is so lessened that, although it is 1,000 feet from steamer to nozzle, the 1¼-inch stream is thrown with the same ease as though the steamer were only 287 feet from the nozzle.

This involves no new principle in hydraulics, and I reiterate it only because I saw it so wofully absent from Lynn a fortnight ago.

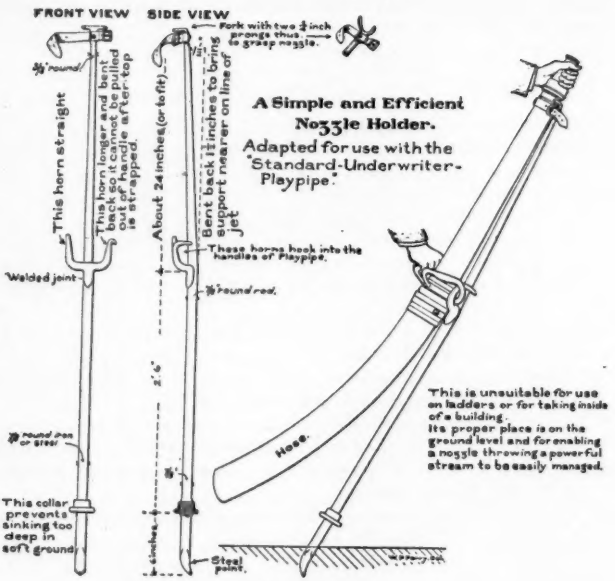

FRONT VIEW
SIDE VIEW
Fork with two ½ inch prongs thus to grasp nozzle.
A Simple and Efficient Nozzle Holder.
Adapted for use with the "Standard-Underwriter-Playpipe."
This horn straight
This horn longer and bent back so it cannot be pulled out of handle after top is strapped.
About 24 inches (or to fit)
Bent back 1½ inches to bring support nearer on line of jet
These horns hook into the handles of Playpipe.
Welded joint
⅜" round rod.
⅜" round iron or steel
This collar prevents sinking too deep in soft ground
2' 6"
8"
6 inches
Steel point.
This is unsuitable for use on ladders or for taking inside of a building. Its proper place is on the ground level and for enabling a nozzle throwing a powerful stream to be easily managed.
Hose

FIG. 25.

A NOZZLE-REST.

Several water-works superintendents have expressed an interest in this handy device, and therefore a cut, from which any intelligent blacksmith can make one, is reproduced here. I devised it a year or two ago for use in factory yards in occasionally testing fire-pumps up to a high pressure when short-handed.

Those of you who manage water-works in cities or towns where the hydrant-pressure is from 100 to 140 pounds per square inch, as is the case at several places in New England, need not be told how difficult it is to hold the hose nozzle under the pressure which this gives, and probably each has seen men tipped over by the recoil when trying alone to hold such powerful streams; and if you will have your blacksmith make one of these, you will be surprised at the ease with which it enables the most powerful stream to be managed.

A pressure of *40 pounds at the nozzle* on a 1¼-inch stream is about all even a skilled hoseman can conveniently manage, without other men to help him. And a nozzle-pressure of 60 pounds with a 1¼-inch stream will tax the energies of three strong men to hold it fast.

The cheap and simple device illustrated in Fig. 25 will enable a single boy to hold and easily direct a 1¼-inch stream under 100-pound nozzle-pressure (which, if hose were 200 feet long, corresponds to 211 pounds water-pressure at the steamer).

The philosophy of the action of this device is very simple. A nozzle or play-pipe always pulls back with a force just equal to force propelling the jet. Action and reaction are equal. Ordinarily the grasp of the pipe-men and the friction on the ground of the hose near the nozzle have to balance this reaction.

This nozzle-rest, however, furnishes a prop *directly on line* with the force or reaction, and balances all this recoil. So all the hand has to do, except when moving to a new position, is merely to guide its direction.

Please not misunderstand me; this is not a universal attachment to be used at all times, for nine-tenths of the work of a fire department any device of this sort would be only in the way, and useless; but whenever it is desired to project a very powerful stream under high pressure, or whenever, as in certain tests, it is desirable to get along with few men, then it may be extremely valuable to have one of these handy.

One topic more and I am done. You are often called upon by mill managers to run your pipes into their mill-yard and your professional judgment invoked to fix up their hydrant system (I wish it were invoked even more frequently). Whenever that mill is liable to come to the "Factory Mutuals" for insurance, I beg you, gentlemen, to bear the following points in mind:—

1st. *Don't lay any 4-inch pipe for hydrant mains* (unless it be a short piece to a single hydrant or to an unimportant part of the yard); 6-inch pipe is none too big for even the branch pipes, and for a factory worth half a million dollars 8 inch is best for the main circuit around the yard. For a big factory a 12-inch pipe into the yard is by no means extravagant. The carrying capacity of water-pipes may deteriorate greatly with age.

2d. *In planting hydrants, plant them so the whole available number of streams can be concentrated on any particular building of importance without using any line of hose more than 250 feet long.*

3d. Remind the mill managers of a fact which they seldom realize (I don't dare admonish you, who have such long experience in the craft, to keep it in mind yourselves in planting hydrants and pipes about town) — *you can furnish stock and labor and lay 100 feet of the best 6-inch iron pipe for just about the same amount of money that it costs your city to buy 100 feet of first-class 2½-inch fire-hose.* The pipe will carry more water than three lines of the fire-hose, and may last for fifty years, while the fire-hose will have to be renewed in five to eight years. *That cast-iron pipes and hydrants are cheaper than hose, is a maxim that all who are laying out fire protection may well remember.*

4th. *Don't run main pipes under buildings* if it can possibly be avoided, and when it must be done, protect and cover them with earth so that the falling of the building may not break them just when most needed.

5th. For large branches into a building *always put a stop-gate outside the building*, and a safe distance from its walls, by which this may be kept from bleeding the hydrant system if a floor of the building falls.

The Best Kind of Fire-Hose for Factories.

I have been asked by several to name the kind of fire-hose preferred for the protection of mills. The needs are somewhat different from those of city fire departments.

We consider that **for attachment to stand-pipes in stair-towers, or for dry well-ventilated places inside the mill, a thoroughly good unlined linen hose is the best**, and for small hose inside the rooms *good* unlined linen is the best.

It is the best by reason of its superior lightness, compactness, and convenience for quick use by but a single man, and because there is little or no chance of its becoming stuck together by the ordinary heat of the rooms; moreover, such in-

side hose need never be used except in case of actual fire; and linen hose, if kept dry, will retain its good quality unimpaired for many years.

It must be remembered, however, that three pieces out of four of the linen hose ordinarily found in the market are made for insurance inspectors to look at, rather than for actual use.

For outside use, or for connection to yard hydrants, rubber-lined cotton hose is very much the best kind.

1st. Because it will not become cut and injured by chafing when lying over sharp corners or sharp gravel nearly so easily as linen does, when subject to the slight vibration due pulsations of fire-pump.

2d. There is very much less loss of pressure by friction in well-made rubber-lined hose than in linen (see page 108), and this makes a serious difference in jet where length is more than 200 feet.

3d. **Rubber-lined hose is best for use in the fortnightly or monthly pump trials**; for whereas linen hose is injured more or less each time it is wet, the durability of rubber-lined hose is improved, if anything, by occasionally running a stream of water through it, providing it is well dried afterward.

For inside hose in dye-works, print-works, or factories where air is very damp, rubber-lined cotton hose will generally prove more durable and satisfactory than linen hose.

Linen possesses the property of absorbing moisture from the air to a greater extent than is generally appreciated.

TABLES FOR PRACTICAL USE.

Table A.

This is, in one sense, the most complete in its details of the three sets of tables presented, and extends from page 136 to page 155.

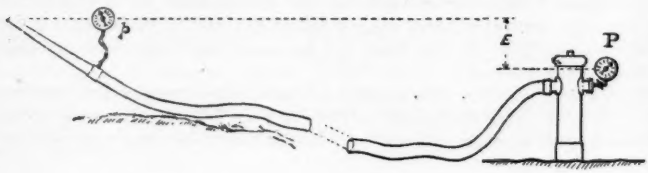
For regular use in pump inspections, Table A is not so convenient as Table B, pages 158 to 163.

For showing the relative difference in pressure lost, according to the diameter or length of the hose used, Table C, page 166, unless changed, is most convenient.

To understand Table A, turn to page 142, or A No. 4. This gives the data for the 1⅛-inch smooth nozzle. The pressure at the base of the play-pipe is the controlling element. This is what throws the water, and thus governs the height of jet, the quantity, and the friction loss.

We see that a "good" average fire stream requires 40 pounds indicated pressure at base of play-pipe.

By indicated pressure, we mean the pressure which a gauge connected to a play-pipe, as shown at *p* in the subjoined sketch, would indicate.



In practice it is seldom convenient to measure the pressure at this point. The pressure is more readily measured at the other end of the hose, at the hydrant or steamer, as shown at P.

Nevertheless, although we do not apply our gauge at the base of the play-pipe, the pressure is there just the same, and is a proper basis for computations.

Turning again to the Table A, No. 4, page 142, and following across the page, we see that for this 40-pound 1½-inch stream, —

The extreme drops, with no wind, will rise to a height of . . .	84 feet.
It will be a good practical fire-stream up to a height of . . .	65 "
If elevated at the best angle (about 32°) it will throw the extreme drops, when there is no wind, to a horizontal distance of . .	142 "
At the same time, keeping the effect of a moderate wind in view, we cannot class it as a good, effective fire-stream for a greater horizontal distance of more than	59 "
(In this the stream is not supposed to be horizontal, but is supposed to be elevated at the ordinary working angle of about 30°, and thus this point 59 feet distant would be up in air high as third-story windows.) The number of gallons per minute discharged will be .	238

Height and Distance Reached by Jets.

Tables heretofore published have given **as the height of a jet** corresponding to a given pressure **the extreme height to which the highest drops of water would rise in still air**, and pumps have often been sold with representations based on such misleading data as to the height they would throw. Such data is almost worthless in considering fire protection, for the obvious reasons: first, that the water cannot be thrown in a direct vertical upon a building in flames; second, that, even if it could, the few scattering drops which would reach this height would be of no avail whatever in extinguishing the fire; third, that air still enough to permit these extreme drops to attain this height is not found more than one day in ten, and almost never during a fire. Few persons have any idea how much influence the wind has upon the height that a jet of water can attain. **Merely a moderate summer afternoon breeze will cut down height of extreme drops 10 or 15 per cent.**

Much attention was given to determine for the different pressures the extreme height at which stream was solid and forcible enough to constitute a **good fire-stream**. It was hard to define this exactly within say 5 feet, and say just exactly where the stream ceased to be "good;" but I tried it under many different circumstances, and present the results as based on my best judgment. Some men would undoubtedly set the limit at 10 per cent. higher, but the effect of a moderate wind was taken into account in determining the figures in the table.

Under favorable conditions, with still air, the stream will be in shape to do good execution at a considerably greater distance.

In defining the limit of height as a good effective fire-stream for a given pressure, I have classed as *good* a stream which, at limit named, would enter through a window and barely strike ceiling with force to spatter wall, and which

at limit named had not lost continuity of stream by dividing into a shower of spray, and which at this limit appeared to shoot $\frac{9}{10}$ of the whole body of water inside a 15-inch circle, and $\frac{3}{4}$ of it within a 10-inch circle, as nearly as could be judged by the eye. In setting upon this limit of height **as a good effective stream, the stream was not vertical, but was inclined upward at 75 degrees**, which may be taken as the highest practical working angle.

With regard to the distance reached by jets, the same general remarks just given will also apply. The distance attained by the extreme drops measured as at a firemen's muster is misleading as practical information for fire protection; but that is the way the values in the ordinary tables are derived. A very faint breeze will increase or decrease the distance reached by the extreme drops by 10 per cent.

In fixing the limit of horizontal distance as a **good effective fire-stream, the stream itself is not supposed horizontal**, but it is supposed to be inclined upward at the ordinary working angle of 30 or 45 degrees.

Continuing to follow across the page to past the middle, we see that if our line of 2½-inch hose is 300 feet long, and including an allowance for the ordinary serpentine course in which it runs, — we see that to maintain this good fire-pressure of 40 pounds at the nozzle will require a pressure at the hydrant or at the steamer of —

If the hose be unlined linen	131 pounds.
" " rubber lined, and with inner surface rough . .	120 "
" " " " and with inner surface extremely smooth	81 "

If we follow across the page to a line of hose whose length is 800 feet (and this is a length often called into actual use) we see that to give a good first-class 1⅛-inch stream at the nozzle requires, if the rubber-lined hose be very rough on the inside, 247 pounds pressure at the steamer. While with the hose of the very smoothest quality, 145 pounds pressure at the steamer will give just the same force to the jet.

Most hose in use in fire departments will come somewhere between these two grades of "inside rough" and "inside smooth," neither of which are exaggerations, but both grades can be found in the market to-day. By reference to the photographs on Fig. 7, page 111, may be seen the exact degree of roughness to which the figures in the following tables apply.

The hose friction varies greatly in different kinds of hose, according to smoothness of inside surface or waterway. As already stated on page 111, salesmen of inferior grades of hose often state with great positiveness (and equal disregard of fact and reason) that "roughness of surface makes no practical difference in flow," that the water lies dead in the little hollows between the ridges, and merely furnishes a cushion on which the main stream slides along," etc. Such notions were conclusively upset by the experiments of the eminent French Engineer Darcy, over thirty years ago; and again proved untrue by the experiments mentioned above. The fact is, that **a rough surface apparently sets the whole stream all the way to its very centre into a**

condition of turmoil and eddying, and all these eddies absorb power. The same is true of iron pipes containing tubercles. **An old tubercle-coated 6-inch pipe, in which there is a clear open waterway 5 inches diameter inside of projecting tubercles, may discharge no more water under a given pressure than would a smooth, clean pipe about 4 inches in diameter.**

In purchasing new hose, departments are advised to insist on a sample being furnished along with the proposal, and to insist that for acceptance the smoothness must in all cases equal that of sample.

Hydraulic Elements on which Table is Based.

Coefficient of discharge, smooth nozzles		.974
" " ring "		.740
Diameter of hose-couplings	2.50	inches.
Actual diameter of ordinary good 2½-inch rubber-lined hose	2⅝	"
" " " " " " unlined linen hose	2⅝	"
" " " inferior " rubber-lined hose	2.50	"

Hose supposed to be laid in a curved or crooked line, as in ordinary practice.

Friction loss per 100 feet, with 240 gallons per minute flowing, assumed to be as follows, including effect of curvature and stretch: —

For very best and smoothest rubber-lined hose	13 lbs.
For inferior rubber lined hose with rough interior	26 lbs
For ordinary linen hose	30 lbs.

These were average values, resulting from the experiments already described.

In the original paper algebraic formulæ were presented, adapted to the solution of various problems, but it has not been thought best to reproduce them here.

¾-INCH SMOOTH

This Table may also be

Hydrant Pressure Required—Discharge

	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle	Effective or Static Pressure at Base of Play Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.0	10	....	18	....	37	5	5	5	6	6	5	6	6	6
	10.	10.1	20	17	36	19	52	11	11	10	12	11	11	13	13	11
	15.	15.1	30	cent. higher.	54	cent. further.	64	16	16	16	17	17	16	19	19	17
	20.	20.2	40	33	72	29	73	22	22	21	23	23	22	26	25	23
Ordinary Fire Pressures.	25.	25.2	50	41	86	33	82	27	27	26	29	28	27	32	31	28
	30.	30.2	59	48	96	37	90	33	32	31	35	34	32	39	38	34
	35.	35.3	69	55	105	41	97	38	38	37	40	40	38	45	44	40
	40.	40.3	78	60	112	44	104	43	43	42	46	46	43	52	50	46
	45.	45.4	86	64	119	47	110	49	48	47	52	51	48	58	57	51
	50.	50.4	93	67	125	50	116	54	54	52	58	57	54	65	63	57
	55.	55.5	99	70	131	52	122	60	59	58	64	63	59	71	69	63
	60.	60.5	104	72	136	54	127	65	65	63	69	68	65	78	76	68
Unusually High Pressures.	65.	65.5	109	74	141	56	132	71	70	68	75	74	70	84	82	74
	70.	70.6	114	76	145	58	137	76	75	73	81	80	75	91	88	80
	75.	75.6	119	78	149	60	142	81	81	79	87	85	81	97	94	85
	80.	80.7	123	79	153	62	147	87	86	84	93	91	86	104	101	91
	85.	85.7	126	80	157	64	151	92	92	89	98	97	92	110	107	97
	90.	90.7	129	81	161	65	156	98	97	94	104	102	97	117	113	102
	95.	95.8	132	82	164	66	160	103	102	99	110	108	102	123	120	108
	100.	100.8	134	83	167	68	164	109	108	105	116	114	108	130	126	114

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE. (This size of Nozzle gives too small a body of water for extinguishing a fire of much size.)

used for ⅞-inch Ring Nozzle.

—Height and Distance of Jet.

TABLE A.—No. 1 (From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
7	7	6	8	8	6	9	8	7	9	9	7	11	10	8	12	11	8
14	14	12	16	15	13	17	16	13	19	17	14	21	20	15	24	22	16
22	21	18	24	23	19	26	24	20	28	26	21	32	30	23	36	34	24
29	28	24	32	30	25	34	32	26	37	35	28	43	40	30	48	45	32
36	35	30	39	38	31	43	41	33	46	44	35	53	50	38	61	56	41
43	41	36	47	45	38	52	49	40	56	52	41	64	60	45	73	67	49
50	48	42	55	53	44	60	57	46	65	61	48	75	70	53	85	78	57
58	55	48	63	60	50	69	65	53	74	70	55	86	80	60	97	89	65
65	62	54	71	68	57	77	73	59	84	79	62	96	90	68	109	101	73
72	69	60	79	75	63	86	81	66	93	87	69	107	100	75	121	112	81
79	76	66	87	83	69	95	89	73	102	96	76	118	110	83	133	123	89
86	83	72	95	90	76	103	97	79	112	105	83	128	119	90	145	134	97
93	90	78	103	98	82	112	106	86	121	114	90	139	129	98	157	145	106
101	97	84	110	105	88	120	114	92	130	122	97	150	139	105	169	156	114
108	104	90	118	113	94	129	122	99	139	131	104	160	149	113	182	168	122
115	111	96	126	120	101	138	130	106	149	140	111	171	159	120	194	179	130
122	117	102	134	128	107	146	138	112	158	148	117	182	169	128	206	190	138
129	124	108	142	135	113	155	146	119	167	157	124	193	179	135	218	201	146
137	131	114	150	143	120	163	154	125	177	166	131	203	189	143	230	212	154
144	138	120	158	150	126	172	163	132	186	175	138	214	199	150	242	223	163

TAKE NOTICE.—The above is pressure at hydrant head *while stream is flowing*. The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

7/8-INCH SMOOTH

This Table may also be

Hydrant Pressure Required—Discharge

INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle		Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5	5.1	11		18		50	6	6	5	6	6	6	8	7	6
	10.	10.2	21	18	37	21	71	12	11	11	13	13	11	16	15	13
	15.	15.2	31	26	56	27	87	17	17	16	19	19	17	23	22	19
	20.	20.3	41	34	74	33	100	23	23	22	26	25	23	31	30	25
Ordinary Fire Pressures.	25.	25.4	51	42	90	38	112	29	29	27	32	31	29	39	37	31
	30.	30.5	61	49	103	42	123	35	34	33	39	38	34	47	45	38
	35.	35.5	71	56	114	46	133	41	40	38	45	44	40	54	52	44
	40.	40.6	81	62	124	49	142	46	46	43	52	50	46	62	59	50
	45.	45.7	89	67	132	52	150	52	51	49	58	57	51	70	67	57
	50.	50.8	97	71	140	55	159	58	57	54	65	63	57	78	74	63
	55	55.8	105	74	147	58	166	64	63	60	71	69	63	85	82	69
	60.	60.9	112	77	153	61	174	70	69	65	78	75	69	93	89	75
Unusually High Pressures.	65.	66.0	118	79	158	64	181	75	74	71	84	82	74	101	96	82
	70.	71.0	123	81	163	66	188	81	80	76	90	88	80	109	104	88
	75.	76.1	128	83	168	68	194	87	86	82	97	94	86	117	111	94
	80.	81.2	132	85	172	70	201	93	91	87	103	101	91	124	119	101
	85.	86.3	136	87	176	72	207	99	97	92	110	107	97	132	126	107
	90.	91.3	139	88	180	74	213	104	103	98	116	113	103	140	134	113
	95.	96.4	142	89	183	75	219	110	109	103	123	119	109	148	141	119
	100.	101.5	144	90	186	76	224	116	114	109	129	126	114	155	148	126

Maximum: is about 10 per cent. higher, "fire stream" limit as a "fair" Maximum

Maximum: is about 12 per cent. farther, "fire stream" limit as a "fair" Maximum

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE.

used for 1-inch Ring Nozzle.

—Height and Distance of Jet.

TABLE A.- No. 2.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'g'h. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9	9	7	10	10	7	12	11	8	13	12	9	16	14	10	18	17	11
18	17	14	21	19	15	23	22	16	26	24	17	31	28	19	37	33	22
27	26	21	31	29	22	35	33	24	39	36	26	47	43	29	55	50	33
36	34	27	42	39	30	47	43	32	52	48	34	63	57	39	73	66	43
45	43	34	52	48	37	59	54	40	65	60	43	78	71	48	91	83	54
54	51	41	62	58	45	70	65	48	78	72	51	94	85	58	110	99	65
64	60	48	73	68	52	82	76	56	91	84	60	109	100	68	128	116	76
73	68	55	83	78	59	94	87	64	104	96	68	125	114	78	146	132	87
82	77	62	94	87	67	105	97	72	117	108	77	141	128	87	164	149	97
91	86	69	104	97	74	117	108	80	130	120	86	156	142	97	183	165	108
100	94	75	114	107	82	129	119	88	143	132	94	172	157	107	201	182	119
109	103	82	125	116	89	140	130	96	156	144	103	188	171	116	219	198	130
118	111	89	135	126	96	152	141	104	169	156	111	203	185	126	237	215	141
127	120	96	145	136	104	164	152	112	182	167	120	219	199	136	255	231	152
136	128	103	156	145	111	175	162	120	195	179	128	234	213	145	....	248	162
145	137	110	166	155	119	187	173	128	208	191	137	250	228	155	....	264	173
154	145	116	177	165	126	199	184	136	221	203	145	....	242	165	...	...	184
163	154	123	187	174	134	211	195	144	234	215	154	....	256	174	....	...	195
173	163	130	197	184	141	222	206	152	247	227	163	....	....	184	....	....	206
182	171	137	208	194	148	234	216	160	260	239	171	....	....	194	....	....	216

TAKE NOTICE.— The above is pressure at hydrant head *while stream is flowing.* The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1-INCH SMOOTH

Hydrant Pressure Required—Discharge

INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.		Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column), through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.1	10	.....	17	....	66	6	6	6	8	7	6	10	9	7
	10.	10.3	21	18	38	21	93	13	12	12	15	14	12	20	18	14
	15.	15.4	32	26	58	30	114	19	19	17	23	22	19	29	27	22
	20.	20.5	43	35	77	37	132	26	25	23	30	29	25	39	37	29
Ordinary Fire Streams. Fair.	25.	25.6	53	43	94	42	147	32	31	29	38	36	31	49	46	36
	30.	30.8	63	51	109	47	161	38	37	34	45	43	37	59	55	43
Good.	35.	35.9	73	58	122	51	174	45	44	40	53	51	44	68	64	51
	40.	41.0	83	64	133	55	186	51	50	46	60	58	50	78	73	58
Excellent.	45.	46.2	98	69	143	58	198	57	56	52	68	65	56	88	83	65
	50.	51.3	101	73	152	61	208	64	62	57	75	72	62	98	92	72
	55.	56.4	109	76	160	64	218	70	69	63	83	79	69	108	101	79
	60.	61.5	117	79	167	67	228	77	75	69	90	87	75	117	110	87
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	66.7	124	82	173	70	237	83	81	75	98	94	81	127	119	94
	70.	71.8	130	85	179	72	246	89	87	80	105	101	87	137	128	101
	75.	76.9	135	87	184	74	255	96	94	86	113	108	94	147	138	108
	80.	82.1	140	89	189	76	263	102	100	92	120	115	100	156	147	115
	85.	87.2	144	91	193	78	274	109	106	98	128	123	106	166	156	123
	90.	92.3	147	92	197	80	279	115	112	103	135	130	112	176	165	130
	95.	97.4	150	94	201	82	287	121	118	109	143	137	118	186	174	137
	100.	102.6	152	96	205	83	295	128	125	115	150	144	125	195	183	144

Maximum Limit as a "fair fire stream" is about 10 per cent. higher.

Maximum Limit as a "fair fire stream" is about 12 per cent. farther.

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE.
—Height and Distance of Jet.

TABLE A.—No. 3.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
12	11	8	14	13	9	17	15	10	19	17	11	23	21	13	28	25	15
24	22	16	29	26	18	33	30	20	38	34	22	47	42	26	56	50	30
36	33	25	43	39	28	50	45	30	57	51	33	70	63	39	84	75	45
48	45	33	57	52	37	66	60	41	75	68	45	93	84	52	111	99	60
60	56	41	71	65	46	83	75	51	94	85	56	117	105	65	139	124	75
72	67	49	86	79	55	99	90	61	113	102	67	140	125	79	167	149	90
84	78	57	100	92	64	116	105	71	132	119	78	163	146	92	195	174	105
96	89	66	114	105	73	132	120	81	151	136	89	187	167	105	223	199	120
108	100	74	129	118	83	149	135	91	169	153	100	210	188	118	251	223	135
120	111	82	143	131	92	166	151	102	188	170	111	233	209	131	....	248	151
132	122	90	157	144	101	182	166	112	207	187	122	....	230	144	....	....	166
144	134	98	171	157	110	199	181	122	226	204	134	....	251	157	....	....	181
156	145	107	186	170	119	215	196	132	244	221	145	....	....	170	....	....	196
168	156	115	200	183	128	232	211	142	....	238	156	....	....	183	....	....	211
181	167	123	214	196	138	248	226	152	....	255	167	....	....	196	....	....	226
193	178	131	229	209	147	....	241	162	..	....	178	....	....	209	....	....	241
205	189	139	243	222	156	....	256	173	....	....	189	....	....	222	....	....	....
217	200	147	257	236	165	....	..	183	....	....	200	....	....	236	....	....	....
229	211	156	....	249	174	....	....	193	....	....	211	....	....	249	....	....	....
241	223	164	....	....	183	....	....	203	....	..	223	....	....	....	....	....	....

TAKE NOTICE. — The above is pressure at hydrant head *while stream is flowing*. The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1⅛-INCH SMOOTH

Hydrant Pressure Required—Discharge

INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.		Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
		lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.		5.	5.2	11		19		84	7	7	6	9	9	7	13	12	9
		10.	10.4	22		18		119	15	14	12	18	17	14	26	24	17
		15.	15.6	32		27		146	22	21	19	27	26	21	38	35	26
		20.	20.8	43		36		168	29	28	25	36	34	28	51	47	34
Ordinary Fire Streams.	Fair.	25.	26.0	54		44		188	36	35	31	45	43	35	64	59	43
		30.	31.2	64		52		206	44	42	37	55	52	42	77	71	52
	Good.	35.	36.4	74		59		222	51	49	43	64	60	49	89	82	60
		40.	41.7	84		65		238	58	56	50	73	69	56	102	94	69
		45.	46.9	94		70		252	65	63	56	82	77	63	115	106	77
	Excellent.	50.	52.1	104		75		266	72	70	62	91	86	70	128	118	86
		55.	57.3	113		80		279	80	77	68	100	95	77	140	130	95
		60.	62.5	122		83		291	87	84	74	109	103	84	153	141	103
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)		65.	67.7	130		86		303	94	91	81	118	112	91	166	153	112
		70.	72.9	136		88		314	101	98	87	127	120	98	179	165	120
		75.	78.1	142		90		325	109	105	93	136	129	105	191	177	129
		80.	83.3	146		92		336	116	112	99	145	138	112	204	188	138
		85.	88.5	150		94		346	123	119	106	154	146	119	217	200	146
		90.	93.7	153		96		356	130	126	112	164	155	126	230	212	155
		95.	98.9	156		98		366	138	133	118	173	163	133	242	224	163
		100.	104.1	158		99		376	145	140	124	182	172	140	255	236	172

NOZZLE. (This is the size preferred for general outside use.) —Height and Distance of Jet.

TABLE A.—No. 4. (From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
16	15	10	20	18	12	24	21	13	28	25	15	35	31	18	42	37	21
33	30	20	40	36	24	48	43	27	55	49	30	70	62	36	84	75	43
49	45	31	60	54	35	71	64	40	82	74	45	105	93	54	127	112	64
66	60	41	80	73	47	95	85	54	110	98	60	139	123	73	168	149	85
82	75	51	101	91	59	119	107	67	137	123	75	174	154	91	211	186	107
99	90	61	121	109	71	143	128	80	165	147	90	209	185	109	253	223	128
115	105	71	141	127	82	166	149	94	192	172	105	243	216	127	...	261	149
131	120	81	161	145	94	190	171	107	220	196	120	278	247	145	....	....	171
148	135	92	181	163	106	214	192	120	247	221	135	..	278	163	....	...	192
164	150	102	201	181	118	238	213	134	274	245	150	...	....	181	....	....	213
181	165	112	221	200	130	262	235	147	....	270	165	....	....	200	....	....	235
197	180	122	241	218	141	....	256	160	....	....	180	....	....	218	....	....	256
214	195	132	261	236	153	....	....	174	....	....	195	....	..	236	....	....	....
230	209	143	....	254	165	....	....	187	....	....	209	....	...	254	....	....	...
246	224	153	....	..	177	....	....	201	....	....	224	....	....	..	....	....	....
263	239	163	....	....	188	....	....	214	..	....	239	....	....	....	....	....	....
....	254	173	....	....	200	..	....	227	...	...	254	....	....	....	....	..	....
....	....	183	....	....	212	....	..	241	....	....	....	....	....	....	....	....	....
....	....	194	....	..	224	....	....	254	....	....	....	....	....	....	....	....	....
....	....	204	....	....	236	....	....	....	....	....	....	....	....	....	....	....	....

TAKE NOTICE. — The above is pressure at hydrant head ***while stream is flowing.*** The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1¼-INCH SMOOTH

Hydrant Pressure Required — Discharge

INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.		Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.3	11	.....	19	....	105	8	8	7	11	11	8	17	15	11
	10.	10.6	22	19	40	22	148	17	16	14	23	21	16	34	31	21
	15.	15.9	33	cent. higher.	28	62	cent. farther.	32	181	25	24	21	34	32	24	51	47	32
	20.	21.2	44	37	83	40	209	34	32	27	45	42	32	68	62	42
Ordinary Fire Streams. Fair.	25.	26.5	55	is about 10 per	46	103	is about 12 per	47	234	42	40	34	57	53	40	85	77	53
	30.	31.8	66		53	119		54	256	51	49	41	68	63	49	102	93	63
Good.	35.	37.1	76		60	134		59	277	59	57	48	79	74	57	119	109	74
	40.	42.4	86		67	148		63	296	68	65	55	91	84	65	136	124	84
Excellent.	45.	47.8	97		72	159		67	314	76	73	62	102	95	73	153	140	95
	50.	53.1	07	fire stream"	77	169	fire stream"	70	331	85	81	68	113	106	81	170	155	106
	55.	58.4	17		81	178		73	347	93	89	75	124	116	89	187	170	116
	60.	63.7	26		85	186		76	363	102	97	82	136	127	97	204	186	127
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	69.0	33	limit as a "fair	88	193	limit as a "fair	79	377	110	105	89	147	137	105	221	201	137
	70.	74.3	40		91	200		81	392	118	113	96	158	148	113	238	217	148
	75.	79.6	45		93	207		83	405	127	121	103	170	158	121	255	232	158
	80.	84.9	50		95	213		85	419	135	129	110	181	169	129	....	248	169
	85.	90.2	54	Maximum	97	219	Maximum	88	432	144	137	116	192	179	137	....	263	179
	90.	95.5	57		99	225		90	444	152	145	123	204	190	145	....	....	190
	95.	100.8	59		100	231		92	456	161	154	130	215	201	154	....	....	201
	100.	106.1	61		101	236		93	468	169	162	137	226	211	162	....	....	211

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE. (This size is well adapted for serious fires where water supply is ample and line of hose not too long.) —Height and Distance of Jet.

TABLE A.—No. 5
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose"—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
23	20	13	28	25	15	34	30	18	40	35	20	51	45	25	63	55	30
46	41	26	57	51	31	68	61	36	80	71	41	103	90	51	125	110	61
68	61	39	85	76	47	102	91	54	120	106	61	154	136	76	188	165	91
91	82	52	114	102	62	137	121	72	159	141	82	205	181	101	251	220	121
114	102	65	142	127	77	171	152	90	199	176	102	256	226	127	....	275	152
136	123	78	171	152	93	205	182	108	239	212	123	....	271	152	....	....	182
159	143	91	199	178	109	239	212	126	279	247	142	....	....	178	....	....	212
182	164	104	227	203	124	273	243	144	....	283	164	....	....	203	....	....	243
205	184	117	256	229	140	....	273	162	....	....	184	....	....	229	....	....	....
227	204	130	....	254	155	....	....	180	....	....	204	....	....	254	....	....	....
249	225	143	....	....	170	....	....	198	....	....	225	....	....	....	....	....	....
....	245	156	....	....	186	....	....	216	....	....	245	....	....	....	....	....	....
....	266	169	....	....	201	....	....	234	....	....	....	....	....	....	....	....	....
....	....	182	....	....	217	....	....	252	....	....	....	....	....	....	....	....	....
....	....	195	....	....	232	....	....	....	....	....	....	....	....	....	....	....	....
....	....	208	....	....	248	....	....	....	....	....	....	....	....	....	....	....	....
....	....	221	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	234	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	247	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	261	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TAKE NOTICE.—The above is pressure at hydrant head *while stream is flowing*. The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1⅜-INCH SMOOTH

Hydrant Pressure Required — Discharge

INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.		Effective or Static Pressure at Base of Play Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at Level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through								
								Length 50 ft.			Length 100 ft.			Length 200 ft.		
								Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
		lbs.	lbs.	ft.	ft.	ft.	ft.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.5	12	.....	19	....	128	10	10	8	15	13	10	23	21	13
	10.	10.9	23	20	41	23	182	20	19	16	29	27	19	46	42	27
	15.	16.4	34	29	63	33	222	31	29	23	44	40	29	69	62	40
	20.	21.5	45	38	85	42	257	41	39	31	58	53	39	92	83	53
Ordinary Fire Streams. Fair.	25.	27.3	56	47	106	49	287	51	48	39	73	67	48	115	104	67
	30.	32.7	67	55	123	56	315	61	58	47	87	80	58	139	125	80
Good.	35.	38.2	78	62	138	62	340	71	67	54	102	94	67	162	146	94
	40.	43.7	89	69	152	68	363	82	77	62	116	107	77	185	166	107
	45.	49.1	100	74	164	70	385	92	87	70	131	120	87	208	187	120
Excellent.	50.	54.6	111	79	175	73	406	102	96	78	145	134	96	231	208	134
	55	60.0	121	83	184	76	426	112	106	86	160	147	106	254	229	147
	60.	65.5	131	87	192	79	445	122	116	93	174	160	116	....	250	160
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	70.9	138	90	200	82	463	133	125	101	189	174	125	....	....	174
	70.	76.4	144	92	207	84	480	143	135	109	203	187	135	....	....	187
	75.	81.9	149	95	214	86	497	153	145	117	218	200	145	....	....	200
	80.	87.3	154	97	220	88	514	163	154	124	232	214	154	....	....	214
	85.	92.8	158	99	226	90	529	174	164	132	247	227	164	....	....	227
	90.	98.2	161	100	232	92	545	184	173	140	261	240	173	....	....	240
	95.	103.7	163	101	238	94	560	194	183	148	....	254	183	....	....	254
	100.	109.1	165	103	243	96	574	204	193	156	....	....	193	....	....	....

Feeble Streams: Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind — 5 lbs.: 12 ft.; 10 lbs.: 20 ft.; 15 lbs.: 29 ft.; 20 lbs.: 38 ft.

Ordinary Fire Streams: Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind — 25 lbs.: 47 ft.; 30 lbs.: 55 ft.; 35 lbs.: 62 ft.; 40 lbs.: 69 ft.; 45 lbs.: 74 ft.; 50 lbs.: 79 ft.; 55 lbs.: 83 ft.; 60 lbs.: 87 ft.

Unusually Strong Streams: Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind — 65 lbs.: 90 ft.; 70 lbs.: 92 ft.; 75 lbs.: 95 ft.; 80 lbs.: 97 ft.; 85 lbs.: 99 ft.; 90 lbs.: 100 ft.; 95 lbs.: 101 ft.; 100 lbs.: 103 ft.

Feeble Streams: Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air — Is about 10 per cent. higher than Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.

Ordinary Fire Streams: Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air — Is about 12 per cent. higher than Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.

Unusually Strong Streams: Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air — Is about 15 per cent. higher than Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.

Feeble Streams: Extreme Horizontal Distance reached by Jet. Average Extreme Drops at Level of Nozzle, with Still Air — 5 lbs.: 19 ft.; 10 lbs.: 41 ft.; 15 lbs.: 63 ft.; 20 lbs.: 85 ft.

Ordinary Fire Streams: Extreme Horizontal Distance reached by Jet. Average Extreme Drops at Level of Nozzle, with Still Air — 25 lbs.: 106 ft.; 30 lbs.: 123 ft.; 35 lbs.: 138 ft.; 40 lbs.: 152 ft.; 45 lbs.: 164 ft.; 50 lbs.: 175 ft.; 55 lbs.: 184 ft.; 60 lbs.: 192 ft.

Unusually Strong Streams: Extreme Horizontal Distance reached by Jet. Average Extreme Drops at Level of Nozzle, with Still Air — 65 lbs.: 200 ft.; 70 lbs.: 207 ft.; 75 lbs.: 214 ft.; 80 lbs.: 220 ft.; 85 lbs.: 226 ft.; 90 lbs.: 232 ft.; 95 lbs.: 238 ft.; 100 lbs.: 243 ft.

Feeble Streams: Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind — 5 lbs.: .... ft.; 10 lbs.: 23 ft.; 15 lbs.: 33 ft.; 20 lbs.: 42 ft.

Ordinary Fire Streams: Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind — 25 lbs.: 49 ft.; 30 lbs.: 56 ft.; 35 lbs.: 62 ft.; 40 lbs.: 68 ft.; 45 lbs.: 70 ft.; 50 lbs.: 73 ft.; 55 lbs.: 76 ft.; 60 lbs.: 79 ft.

Unusually Strong Streams: Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind — 65 lbs.: 82 ft.; 70 lbs.: 84 ft.; 75 lbs.: 86 ft.; 80 lbs.: 88 ft.; 85 lbs.: 90 ft.; 90 lbs.: 92 ft.; 95 lbs.: 94 ft.; 100 lbs.: 96 ft.

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE.
—Height and Distance of Jet.

TABLE A.—No. 6.
(From experiments of J. R. FREEMAN, 1888.)

Steamer while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth, 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
32	28	17	40	36	21	49	43	25	57	51	28	74	66	36	92	80	43
63	56	34	81	71	42	98	86	49	115	101	56	149	131	71	184	161	86
95	85	51	121	107	62	147	129	74	172	152	85	224	196	107	275	241	129
127	113	68	161	143	83	195	173	98	230	202	113	299	262	143	....	321	173
158	141	85	201	178	104	244	216	123	287	253	141	....	....	178	....	....	216
190	169	103	242	214	125	293	259	147	....	....	169	....	....	214	....	....	259
222	198	120	282	250	146	....	....	172	....	....	198	....	....	250	....	....	....
253	226	137	....	....	166	....	....	196	....	....	226	....	....	....	....	....	....
....	254	154	....	....	187	....	....	221	....	....	254	....	....	....	....	....	....
....	....	171	....	....	208	....	....	245	....	....	....	....	....	....	....	....	....
....	....	188	....	....	229	....	....	270	....	....	....	....	....	....	....	....	....
....	....	205	....	....	250	....	....	....	....	....	....	....	....	....	....	....	....
....	....	222	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	239	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	256	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
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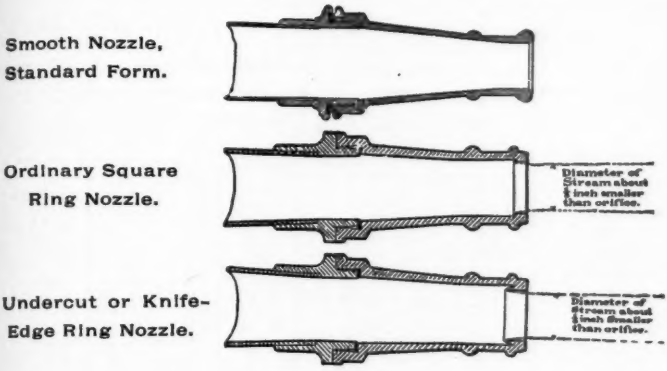
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TAKE NOTICE.—The above is pressure at hydrant head *while stream is flowing.* The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.


Smooth Nozzle,
Standard Form.
Ordinary Square
Ring Nozzle.
Diameter of Stream about ⅛ inch smaller than orifice.
Undercut or Knife-
Edge Ring Nozzle.
Diameter of Stream about ⅛ inch Smaller than orifice.

RING NOZZLES.

We find so many ring nozzles in use that it was thought best to prepare tables giving their discharge. The advocates of this style of nozzle stand up for its alleged merits stoutly, and therefore, as already stated, I tried some experiments intended to settle the question. Ring nozzles were prepared of such size as to discharge just the same number of gallons per minute as certain smooth nozzles, and the two, ring and smooth, then tested side by side. One set of these experiments is illustrated in the cut opposite. Another series of experiments was tried at another place, with jets more nearly horizontal. Both series of experiments were made with the greatest care, and at times when there was almost absolutely no wind; and were afterward repeated in the presence of the corps of inspectors.

These experiments all showed conclusively that the ring nozzle does not possess the slightest advantage over the smooth nozzle. The smooth nozzle proved slightly superior: its stream was more solid, and reached a little farther; this difference was very small, however.

Other experiments proved that **a ring nozzle discharges only three-quarters as much water per minute as a smooth nozzle of the same size.** The sharp corner of the ring contracts the stream, and if any one will measure diameter of stream close to nozzle with a pair of common machinist's calipers, he will find it about ⅛ inch smaller than the hole from which it issues.

The only use of the ring nozzle is to make a show of playing a larger stream than is the fact. The apparent advantage of the ring nozzle, which has misled many firemen, is easily explained. **The result is the same as if a smaller nozzle were used,** while hydrant-pressure remained the same. The number of gallons per minute flowing being less, the pressure lost by friction through hose is less; therefore pressure at base of play-pipe remains greater, therefore stream goes higher.

For ¾-inch and 1-inch ring nozzles the discharge is almost exactly the same as for smooth nozzles ⅛ inch smaller; therefore no special tables for these two sizes of ring nozzles are given. **For 7-8-inch Ring Nozzle use table for 3-4-inch Smooth Nozzle, and for 1-inch Ring Nozzle use table for 7-8-inch Smooth Nozzle.**

(Discharge of 1-in. Ring is same as 7/8-in. Smooth.)
(Discharge of 7/8-in. Ring is same as 3/4-in. Smooth.)

1 1/8-INCH RING

Hydrant Pressure Required—Discharge

INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.		Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
		lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.		5.	5.1	10		17		63	6	6	6	7	7	6	9	9	7
		10.	10.2	21	17	37	20	89	13	12	11	15	14	12	19	18	14
		15.	15.4	32	26	57	29	110	19	18	17	22	21	18	28	27	21
		20.	20.5	42	34	76	36	126	25	25	23	29	28	25	38	35	28
Ordinary Fire Streams.	Fair.	25.	25.6	52	42	93	41	141	31	31	28	37	35	31	47	44	35
		30.	30.7	62	49	107	45	155	38	37	34	44	42	37	56	53	42
	Good.	35.	35.8	72	56	120	49	167	44	43	40	51	49	43	66	62	49
		40	40.9	82	62	131	53	179	50	49	45	59	56	49	75	71	56
	Excellent.	45.	46.0	91	67	141	56	190	56	55	51	66	63	55	85	80	63
		50.	51.2	99	70	150	59	200	63	61	57	73	70	61	94	88	70
		55.	56.3	107	73	158	62	210	69	67	63	80	77	67	103	97	77
		60.	61.4	115	76	164	65	219	75	74	68	88	84	74	113	106	84
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)		65.	66.5	122	79	170	67	228	82	80	74	95	91	80	122	115	91
		70.	71.6	128	82	176	69	237	88	86	80	102	98	86	132	124	98
		75.	76.7	133	84	181	71	245	94	92	85	110	106	92	141	133	106
		80.	81.8	138	86	186	73	253	100	98	91	117	113	98	150	141	113
		85.	87.0	142	88	190	75	261	107	104	97	124	120	104	160	150	120
		90.	92.1	145	89	194	77	268	113	110	102	132	127	110	169	159	127
		95.	97.2	148	91	198	79	276	119	117	108	139	134	117	179	168	134
		100.	102.3	150	93	202	80	283	125	123	114	146	141	123	188	177	141

(Fair. / Good. / Excellent. — "about 10 per cent. higher." / "about 12 per cent. farther." / "fire stream" is about the limit as a "fair" fire stream. / Maximum)

NOTE.—The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "undercut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about three per cent. less than quantity given above.

NOZZLE.
—Height and Distance of Jet.

TABLE A.—No. 7.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
12	11	8	14	12	9	16	14	10	18	16	11	22	20	12	26	23	14
23	21	16	27	25	18	31	29	19	35	32	21	44	39	25	52	47	29
34	32	24	41	37	27	47	43	29	53	48	32	66	59	37	78	70	43
46	43	32	54	50	35	63	57	39	71	64	43	88	79	50	104	93	57
57	53	40	68	62	44	78	71	49	89	80	53	110	98	62	130	116	71
69	64	48	81	75	53	94	86	58	106	96	64	131	118	75	156	140	86
80	75	56	95	87	62	110	100	68	124	112	75	153	138	87	182	163	100
92	85	64	108	100	71	125	114	78	142	128	85	175	157	100	208	186	114
103	96	71	122	112	80	141	128	88	160	145	96	197	177	112	234	209	128
115	106	79	136	125	88	156	143	97	177	161	106	219	197	125	260	233	143
126	117	87	149	137	97	172	157	107	195	177	117	241	216	137	....	256	157
138	128	95	163	149	106	188	171	117	213	193	128	263	236	149	....	....	171
149	138	103	176	162	115	203	185	127	230	209	138	....	256	162	....	....	185
161	149	111	190	174	124	219	200	136	248	225	149	....	....	174	....	....	200
172	160	119	203	187	132	235	214	146	266	241	160	....	....	187	....	....	214
184	170	127	217	199	141	250	228	156	....	257	170	....	....	199	....	....	228
195	181	135	231	212	150	....	242	166	....	....	181	....	....	212	....	....	242
207	192	143	244	224	159	....	257	175	....	....	192	....	....	224	....	....	257
218	202	151	258	237	168	....	....	185	....	....	202	....	....	237	....	....	....
230	213	159	....	249	177	....	....	195	....	....	213	....	....	249	....	....	....

TAKE NOTICE. — **The above is pressure at hydrant head *while stream is flowing*. The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.**

1¼-INCH RING

Hydrant Pressure Required—Discharge

INDICATED PRESSURE by Gange attached at Base of Play-Pipe, and set level with End of Nozzle.		Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet.		Extreme Horizontal Distance reached by Jet.		Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through								
			Average of Highest Drops, Vertical Jet, Still Air.	Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Average Extreme Drops at level of Nozzle, with Still Air.	Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.		Length 50 ft.			Length 100 ft.			Length 200 ft.		
								Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
		lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.		5.	5.2	11	....	20	....	79	7	7	6	9	8	7	12	11	8
		10.	10.4	21	17	39	21	111	14	13	12	17	16	13	24	22	16
		15.	15.5	32	cent. higher.	58	30	136	21	20	18	26	24	20	35	33	24
		20.	20.7	43	35	78	37	157	28	27	24	34	33	27	47	44	33
Ordinary Fire Streams.	Fair.	25.	25.9	53	43	97	42	176	35	34	30	43	41	34	59	55	41
		30.	31.1	63	49	112	48	192	42	40	36	51	49	40	71	66	49
	Good.	35.	36.2	73	56	126	51	208	49	47	42	60	57	47	82	76	57
		40.	41.4	83	63	138	55	222	56	54	48	69	65	54	94	87	65
		45.	46.6	93	68	149	59	236	63	61	54	77	73	61	106	98	73
	Excellent.	50.	51.8	102	72	157	62	248	70	67	61	86	81	67	118	109	81
		55.	57.0	111	76	164	65	260	77	74	67	94	90	74	130	120	90
		60.	62.1	119	79	172	68	272	84	81	73	103	98	81	141	131	98
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)		65.	67.3	127	81	178	71	283	90	88	79	111	106	88	153	142	106
		70.	72.5	133	84	185	73	294	97	94	85	120	114	94	165	153	114
		75.	77.7	138	86	191	75	304	104	101	91	129	122	101	177	164	122
		80.	82.8	143	88	196	77	314	111	108	97	137	130	108	188	175	130
		85.	88.0	147	90	201	79	324	118	115	103	146	138	115	200	186	138
		90.	93.2	149	92	206	81	333	125	121	109	154	147	121	212	197	147
		95.	98.4	152	94	211	82	342	132	128	115	163	155	128	224	208	155
		100.	103.5	154	95	215	84	351	139	135	121	171	163	135	236	218	163

Maximum limit as a "fair fire stream"

NOTE.—The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "undercut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about three per cent. less than quantity given above.

NOZZLE.
—Height and Distance of Jet.

TABLE A.—No. 8.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
15	14	10	18	17	11	21	19	12	25	22	14	31	28	17	38	33	19
30	27	19	36	33	22	43	39	25	49	44	27	62	55	33	75	66	39
45	41	29	55	49	33	64	58	37	74	66	41	93	83	49	112	100	58
60	55	38	73	66	44	86	77	49	99	88	55	124	111	66	150	133	77
75	69	48	91	83	55	107	96	62	123	110	69	155	138	83	187	166	96
90	82	57	109	99	66	128	116	74	148	132	82	186	166	99	225	199	116
105	96	67	127	115	76	150	135	86	172	154	96	217	193	115	262	232	135
•120	110	76	146	132	87	171	154	99	197	176	110	248	221	132	....	266	154
135	123	86	164	148	98	193	173	111	222	199	123	279	249	148	....	....	173
150	137	95	182	165	109	214	193	123	246	221	137	....	276	165	....	....	193
165	151	105	200	181	120	236	212	135	271	243	151	....	....	181	....	....	212
180	164	114	218	198	131	257	231	148	....	265	164	....	....	198	....	....	231
195	178	124	237	214	142	....	251	160	....	....	178	....	....	214	....	....	251
210	192	133	255	231	153	....	....	172	....	....	192	....	....	231	....	....	....
225	206	143	....	247	164	....	....	185	....	....	206	....	....	247	....	....	....
240	219	152	....	264	175	....	....	197	....	....	219	....	....	264	....	....	....
255	233	162	....	....	186	....	....	209	....	....	233	....	....	....	....	....	....
....	247	172	....	....	197	....	....	222	....	....	247	....	....	....	....	....	....
....	260	181	....	....	208	....	....	234	....	....	260	....	....	....	....	....	....
....	....	191	....	....	218	....	....	246	....	....	....	....	....	....	....	....	....

TAKE NOTICE. — The above is pressure at hydrant head *while stream is flowing*. The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1 3/8-INCH RING

Hydrant Pressure Required — Discharge

INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.		Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.3	11		20		96	8	8	7	10	10	8	15	14	10
	10.	10.5	22	17	39	21	136	16	15	13	21	19	15	30	28	19
	15.	15.8	32	27	59	31	166	24	23	20	31	29	23	45	41	29
	20.	21.1	43	36	79	38	192	32	30	26	41	39	30	60	55	39
Ordinary Fire Streams. Fair.	25.	26.3	53	44	99	45	214	40	38	33	52	48	38	75	69	48
	30.	31.6	64	51	116	50	235	48	46	39	62	58	46	91	83	58
Good.	35.	36.8	74	58	131	55	253	55	53	46	72	68	53	106	97	68
	40.	42.1	85	64	144	59	271	63	61	53	82	77	61	121	111	77
Excellent.	45.	47.4	95	69	154	63	287	71	68	59	93	87	68	136	124	87
	50.	52.6	105	74	164	66	303	79	76	66	103	97	76	151	138	97
	55.	57.9	114	78	172	69	318	87	84	72	113	106	84	166	152	106
	60.	63.2	123	81	180	72	332	95	91	79	124	116	91	181	166	116
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	68.4	131	84	187	75	346	103	99	85	134	126	99	196	180	126
	70.	73.7	137	86	194	77	359	111	106	92	144	135	106	211	193	135
	75.	79.0	142	88	200	79	371	119	114	98	155	145	114	226	207	145
	80.	84.2	147	90	206	81	383	127	122	105	165	155	122	241	221	155
	85.	89.5	150	92	212	82	395	135	129	112	175	164	129	257	235	164
	90.	94.7	153	94	217	84	407	143	137	118	186	174	137	....	249	174
	95.	100.0	156	96	222	86	418	150	144	125	196	184	144	....	263	184
	100	105.3	158	97	227	88	429	158	152	131	206	193	152	....	....	193

"1 inch stream" "fire stream" "fair limit as a good effective fire stream" Maximum

NOTE.—The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "undercut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about three per cent. less than quantity given above.

NOZZLE.
—Height and Distance of Jet.

TABLE A.—No. 9.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
20	18	12	25	22	14	29	26	16	34	30	18	44	39	22	53	47	26
40	36	24	49	44	28	59	53	32	68	61	36	88	77	44	107	94	53
60	54	35	74	66	41	88	79	48	103	91	54	131	116	66	160	141	79
79	72	47	99	88	55	118	105	64	137	122	72	175	155	88	213	188	105
99	90	59	123	111	69	147	131	79	171	152	90	219	193	111	267	235	131
119	108	70	148	133	83	177	157	95	205	182	108	263	232	133	....	282	157
139	126	82	173	155	97	206	184	111	240	213	126	....	271	155	....	...	184
159	144	94	197	177	111	236	210	127	274	243	144	....	....	177	....	....	210
179	162	106	222	199	124	265	236	143	....	274	162	....	....	199	....	....	236
199	180	117	247	221	138	....	263	159	....	....	180	....	....	221	....	....	263
219	198	129	271	243	152	....	....	175	....	....	198	....	....	243	....	....	....
238	216	141	....	265	166	....	....	191	....	....	216	....	....	265	....	....	....
258	234	153	....	....	180	....	....	207	....	....	234	....	....	....	....	....	....
....	251	164	....	....	193	....	....	222	....	....	251	....	....	....	....	....	....
....	....	176	....	....	207	....	....	238	....	....	....	....	....	....	....	....	....
....	....	188	....	....	221	....	....	254	....	....	....	....	....	....	....	....	....
....	....	200	....	....	235	....	....	....	....	....	....	....	....	....	....	....	....
....	....	211	....	....	249	....	....	....	....	....	....	....	....	....	....	....	....
....	....	223	....	....	263	....	....	....	....	....	....	....	....	....	....	....	....
....	....	235	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TAKE NOTICE.—The above is pressure at hydrant head *while stream is flowing*. The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

Table B.

PUMP INSPECTION TABLES.

These were designed primarily for the use of insurance inspectors or mill superintendents, for testing fire-pumps, to see if they were in good order, and would deliver as many gallons per minute as they were rated to throw.

The 1¼-inch smooth nozzle stream, with a pressure of 40 or 45 pounds at nozzle, is the standard fire-stream used as basis for estimating capacities of fire-pumps, and in general a hydrant-pressure of 80 to 100 pounds is considered most desirable.

These tables (B, No. 1, and B, No. 2) are also very convenient for the use of water-works superintendents in measuring the water used for special purposes. It will be seen that the amount discharged varies with the quality of the hose, but by the use of a little judgment in interpolating between the values for very smooth hose and very rough hose, according to the grade used, the tables will give results which are certain within five per cent., and generally closer than this, and close enough for most practical purposes.

The results will be a little more accurate when 50 feet of hose is used than for 100 feet, since the effect of any peculiarity in the hose is proportionately less.

These tables are of use as a convenient means of measuring the number of gallons that a pipe system can supply in a given part of the city without reducing the pressure below a certain limit.

If it is desired to know the discharge of a nozzle on a line of hose longer than 100 feet, Table A may be used, thus: Suppose nozzle is 1¼ inch smooth, line of hose medium rough and 500 feet long, hydrant pressure, 150 pounds.

Looking in Table A, No. 5, under column headed "Length 500 feet," and interpolating:

We see that with smoothest hose, gallons per minute = 302.
We see that with rough hose, gallons per minute = 232.

Thus the discharge would be somewhere between these two.

---

[1] These tables are not designed for the exact gauging of discharge of pumping-engines, mentioned on page 103.

To get the very great accuracy mentioned on page 102 requires a special piezometer close to play-pipe and a very careful measurement of diameter of nozzle orifice, and will generally involve a special computation.

PUMP INSPECTION

Discharge of Nozzles attached

HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	1⅜-Inch Smooth Nozzle. Gals. per Min.			1¼-Inch Smooth Nozzle. Gals. per Min.			1⅛-Inch Smooth Nozzle. Gals. per Min.			1-Inch Smooth Nozzle. Gals. per Min.			⅞-Inch Smooth Nozzle, or 1-inch Ring Nozzle. Gals. per Min.		
Lbs. per sq. in.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
5	90	92	103	80	82	90	70	71	75	59	59	62	47	47	48
10	127	131	146	114	116	127	99	101	107	83	84	87	66	67	68
15	155	160	179	140	143	154	121	123	131	101	102	106	81	81	84
20	180	185	206	161	164	179	140	142	151	117	118	123	93	94	96
25	201	207	230	180	184	200	156	158	169	131	132	137	104	105	107
30	220	226	251	197	202	219	171	173	184	143	144	150	114	115	118
35	238	245	272	213	218	236	184	188	199	154	156	162	123	124	127
40	255	262	291	227	233	253	197	201	213	165	167	173	132	133	136
45	270	278	309	241	247	269	209	213	226	175	177	184	140	141	144
50	284	293	325	255	260	283	221	224	238	184	186	194	147	148	152
55	298	307	341	267	273	296	232	235	250	193	195	204	154	155	159
60	311	320	357	279	285	309	242	245	261	202	204	213	161	162	167
65	324	333	371	290	296	322	252	255	272	210	213	221	168	169	173
70	336	346	385	301	307	334	261	265	281	218	221	230	174	176	180
75	348	358	399	311	318	344	270	275	291	226	228	238	181	182	186
80	359	370	412	322	329	357	279	284	301	233	236	246	186	188	192
85	371	382	425	332	339	369	288	293	310	240	243	253	192	193	198
90	381	393	437	341	349	379	296	301	319	247	250	261	197	199	204
95	392	403	449	350	358	390	304	309	328	253	257	268	203	204	209
100	402	414	461	359	368	400	312	317	337	260	264	275	208	210	215

Quantities are stated in United States gallons of 231 cubic inches.

TABLES.

to 50 Feet of 2½-inch Hose.

TABLE B.—No. 1.
(From experiments of J. R. FREEMAN, 1888.)

¾-Inch Smooth Nozzle, or ¾-inch Ring Nozzle. Gals. per Min.			1⅜-Inch Ring Nozzle. Gals. per Min.			1¼-Inch Ring Nozzle. Gals. per Min.			1⅛-Inch Ring Nozzle. Gals. per Min.			HYDRANT PRESSURE.
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Lbs. per sq. in.
36	36	37	75	76	84	66	67	70	56	56	59	5
50	50	51	108	110	118	94	96	101	80	81	84	10
61	61	62	132	135	144	115	117	124	98	99	103	15
71	71	72	152	155	167	133	135	143	113	114	119	20
79	80	81	170	174	187	149	151	159	126	128	133	25
86	87	88	187	191	205	163	165	175	138	140	145	30
93	93	95	201	206	221	176	179	189	149	151	157	35
100	100	101	215	219	237	188	191	202	159	162	168	40
106	106	108	229	233	251	200	203	214	169	172	178	45
112	112	113	241	245	264	211	214	226	179	181	188	50
117	117	119	253	257	277	221	224	237	187	189	197	55
122	122	124	264	269	289	231	234	247	196	198	205	60
127	127	129	275	280	301	240	244	257	205	206	214	65
132	132	134	285	291	313	249	253	267	212	213	222	70
137	137	139	295	301	324	258	262	276	219	221	230	75
141	142	144	305	311	334	266	270	285	226	228	237	80
145	146	148	314	320	345	274	279	294	233	235	244	85
149	150	152	323	329	355	282	287	303	239	242	252	90
153	154	156	332	338	364	290	295	311	246	249	259	95
158	159	161	340	347	374	298	303	319	253	255	266	100

NOTE. — The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "under-cut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about 3 per cent. less than quantity given above.

PUMP INSPECTION

Discharge of Nozzles attached

HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	1⅜-Inch Smooth Nozzle. Gals. per Min.			1¼-Inch Smooth Nozzle. Gals. per Min.			1⅛-Inch Smooth Nozzle. Gals. per Min.			1-Inch Smooth Nozzle. Gals. per Min.			⅞-Inch Smooth Nozzle, or 1-inch Ring Nozzle. Gals. per Min.		
Lbs. per sq. in.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
5	75	79	93	70	72	82	62	64	71	54	55	59	44	45	47
10	107	111	131	98	102	116	88	91	100	76	78	83	63	63	66
15	131	136	160	121	125	143	108	111	123	93	95	102	76	77	81
20	151	157	185	139	144	164	125	128	142	107	110	118	88	89	94
25	169	176	207	155	161	184	139	143	158	120	122	132	99	100	105
30	185	192	226	170	176	202	152	156	173	132	134	144	108	110	115
35	200	208	245	184	190	218	165	169	188	142	145	156	117	119	124
40	214	222	262	197	204	233	176	181	201	152	155	167	125	127	133
45	226	236	278	209	216	247	187	192	213	161	165	177	132	134	141
50	239	249	293	220	228	260	197	202	224	170	174	186	139	142	148
55	251	261	307	231	239	273	207	212	235	178	182	195	146	148	155
60	261	273	320	241	250	285	216	222	245	186	190	204	153	155	162
65	272	284	333	251	260	296	225	231	255	194	198	213	159	161	169
70	282	294	346	261	270	307	233	240	265	201	205	221	165	167	176
75	292	304	358	270	279	319	241	248	275	208	212	228	171	173	182
80	301	314	370	278	288	329	249	256	284	215	219	236	177	179	188
85	311	324	382	287	297	339	257	264	293	222	226	243	182	185	193
90	320	333	393	295	306	349	264	272	301	228	233	250	188	190	199
95	329	342	403	303	314	358	272	279	309	234	239	257	192	195	204
100	337	351	414	311	322	368	279	287	317	240	245	264	197	200	210

Quantities are stated in United States gallons of 231 cubic inches

TABLES.

to 100 Feet of 2½-inch Hose.

TABLE B.—No. 2.
(From experiments of J. R. FREEMAN, 1888.)

¾-inch Smooth Nozzle, or ¼-inch Ring Nozzle. Gals. per Min.			1⅜-inch Ring Nozzle. Gals. per Min.			1¼-inch Ring Nozzle. Gals. per Min.			1⅛-inch Ring Nozzle. Gals. per Min.			HYDRANT PRESSURE.
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Lbs. per sq. in.
34	34	35	67	69	78	60	62	68	52	53	57	5
48	49	50	94	97	110	85	87	96	74	75	81	10
59	60	61	115	120	135	104	107	117	90	92	99	15
68	69	71	133	138	155	120	123	135	105	107	114	20
76	77	79	149	154	174	134	138	151	117	119	128	25
84	84	87	163	169	191	147	151	165	128	130	140	30
90	91	93	176	182	206	159	163	179	139	141	151	35
97	97	100	188	195	219	169	174	191	148	151	162	40
103	103	106	200	207	233	180	185	203	157	160	172	45
108	109	112	211	218	245	190	195	214	165	169	181	50
113	114	117	221	229	257	199	204	224	173	177	189	55
118	119	122	231	239	269	208	213	234	181	185	198	60
123	124	127	241	248	280	217	222	244	189	192	206	65
128	129	132	250	258	291	225	230	253	195	199	213	70
132	133	137	259	267	301	233	239	262	203	206	221	75
137	138	142	267	275	311	240	246	270	209	213	228	80
141	142	146	275	284	320	247	254	279	215	219	235	85
145	146	150	283	292	329	255	261	287	222	226	242	90
149	150	154	291	300	338	262	269	295	228	232	249	95
153	154	158	299	308	347	269	275	302	234	238	255	100

NOTE.—**The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.**

Ring Nozzles with "under-cut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about 3 per cent. less than quantity given above.

PUMP INSPECTION

The degree of accuracy attained in estimating of the two preceding tables — $1\frac{1}{4}$ No. 1 and

HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown. Lbs. per sq. in.	Quantity of Water Discharged per minute through ordinary 2½-inch Fire Hose, (United States Gallons of 231 cubic inches.) Open Hose Butt. No Play-								
	Length 25 feet.			Length 50 feet.			Length 100 feet.		
	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.
10	231	242	297	176	188	242	132	140	188
15	283	297	363	217	230	297	161	171	230
20	326	343	419	251	266	343	186	199	266
25	365	383	468	281	297	383	208	222	297
30	400	420	514	307	326	420	228	243	326
35	432	453	554	332	352	453	246	262	352
40	462	484	593	355	376	484	264	280	376
45	490	514	630	377	399	514	280	297	399
50	516	542	664	398	420	542	294	313	420
55	541	568	696	416	440	568	308	328	440
60	565	594	726	434	460	594	322	343	460
65	588	618	756	452	480	618	336	358	480
70	610	641	784	470	498	641	348	371	498
75	632	663	812	486	515	663	360	384	515
80	652	685	....	502	532	685	372	397	532
85	672	706	....	518	548	706	383	409	548
90	692	727	....	533	564	727	394	421	564
95	712	747	....	547	579	747	405	432	579
100	730	766	....	561	594	766	416	443	594
110	766	806	....	588	623	806	436	465	623
120	800	....	....	614	651	....	456	486	651

greater. greater. greater. greater. greater. greater. greater. greater. greater.

be 5 per cent. be 5 per cent. be 9 per cent. be 3 per cent. be 8 per cent. be 6 per cent. be 1½ per cent.

discharge would discharge would discharge would discharge would discharge would discharge would discharge would

were of Style A. were of Style A. were of Style A. were of Style A. were of Style A. were of Style A. were of Style A.

If Hydrant If Hydrant If Hydrant If Hydrant If Hydrant If Hydrant If Hydrant

NOTE. — The above values are based on experiments with these kinds of Hose attached to a Chapman 4-way Independent Gate Hydrant (Coeff. Disch. by Expt. 0.7[illegible]. So far as influence of kind of Hydrant upon discharge is concerned, the same values are correct enough for practical purposes, except as noted in margin of columns.

It will be noted that this table gives, for each length, the discharge through the best or smoothest hose, and gives, also, discharge for same length of Hose with roughest water-way. By use of a little judgment in interpolating between these two values, error, in ordinary use of table need not exceed 10 per cent.

TABLES.—"Open Butts."

TABLE B.—No. 3.

discharge through "Open Butt" is, not nearly so great as may be attained by the methods B, No. 2 — by reason of greater influence of form of Hydrant and differences in Hose.

with Couplings of 2½-inch Bore. Pipe or Nozzle attached.				Discharge through Open Butt of Hydrant, without Hose attached.	
Length 200 feet.		Length 400 feet.		HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	Discharge of One Nipple of Chapman 4-Way Independent Gate Hydrant.
Inferior Rubber-lined Cotton "Mill Hose."	Ordinary best quality Rubber-lined Hose.	Inferior Rubber-lined Cotton "Mill Hose."	Ordinary best quality Rubber-lined Hose.		Diameter of Outlet exactly 2⅛ inches.
Inside Rough.	Inside Smooth.	Inside Rough.	Inside Smooth.	Lbs. per sq. in.	Gals. per Min.
102	140	74	102	10	419
125	171	90	125	15	513
144	199	104	144	20	592
161	222	116	161	25	663
177	243	127	177	30	725
190	262	137	190	35	783
204	280	146	204	40	837
217	297	155	217	45	888
228	313	164	228	50	936
239	328	172	239	55	982
250	343	179	250	60	1026
260	358	186	260	65	1067
270	371	194	270	70	1108
279	384	201	279	75	1147
288	397	208	288	80	1184
297	409	215	297	85	1221
306	421	221	306	90	1256
314	432	227	314	95	1290
322	443	232	322	100	1326
338	465	243	338	110	....
354	486	254	354	120	....

NOTE. — Slight peculiarities of construction in different makes of Hydrants so affect discharge from open butts of Hydrants without Hose, that these figures apply only approximately to discharge of Hydrants in general.

By using good judgment in applying corrections as per notes below, results accurate to within 10 per cent. may generally be obtained.

(Style A.)—Ordinary Matthews (R. D. Wood & Co.'s) Hydrant without independent gates, inside corner being rounded off, will probably discharge about 20 per cent. more.

(Style B.)— Ordinary Chapman Hydrants without independent gates have square inside corners, and will probably discharge about 10 per cent. more.

For the ordinary Ludlow and Lowry Independent-Gate Hydrants or Chucks, figures in table are probably nearly correct.

If diameter of outlet is not exactly 2⅛ inches, an additional correction, as follows, must be made: —

Diameter.	Add.	Deduct.
2⅝	10 %	....
$2\frac{9}{16}$	5 %	....
$2\frac{7}{16}$	....	5 %
2⅜	....	10 %
2¼	....	19 %

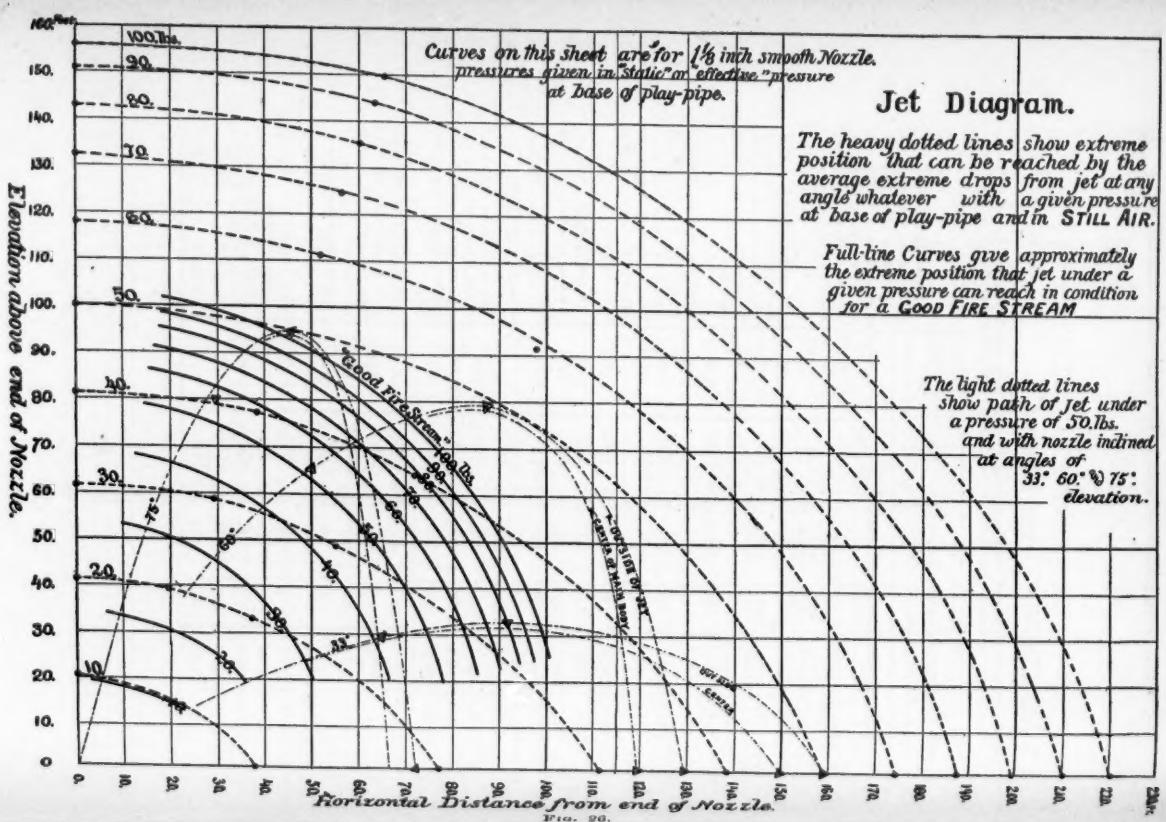

Curves on this sheet are for 1⅛ inch smooth Nozzle.
pressures given in "Static" or effective "pressure at base of play-pipe.
Jet Diagram.
The heavy dotted lines show extreme position that can be reached by the average extreme drops from jet at any angle whatever with a given pressure at base of play-pipe and in STILL AIR.
Full-line Curves give approximately the extreme position that jet under a given pressure can reach in condition for a GOOD FIRE STREAM
The light dotted lines show path of jet under a pressure of 50 lbs. and with nozzle inclined at angles of 33° 60° & 75° elevation.
"Good Fire Stream" 100 lbs.
"OUTSIDE OF JET"
CENTRE OF MAIN BODY
VERY FINE SPRAY
Elevation above end of Nozzle.
Horizontal Distance from end of Nozzle.

FIG. 26.

Jet Diagram. — Fig. 26.

This contains information in very handy form as to the distance a jet can reach in any direction whatever.

It applies particularly to the 1¼-inch jet, but for nearly all practical purposes will answer for jets of from 1 inch to 1½ inches in diameter.

Table C.

This is of interest mainly in illustrating what can be done with a given hydrant-pressure, according to length and kind of hose used.

Note the difference in effective height and force of jet, dependent on whether 500 feet or even 250 feet of hose is used, or whether 50 feet is used, as in the ordinary practice test.

Note, also, the inferiority of linen hose for use in long lines, such as are called for in connection with yard hydrants.

Thus suppose that at a given mill there is available a static pressure of 80 pounds, and that the hydrant pipes are of such ample size that pressure at hydrant will be 70 pounds when streams are playing.

We see from table that if 1¼-inch nozzles are used, the height of the effective fire-streams obtainable will be: —

With 50-foot line of 2½-in. linen hose	73 feet.
" 250 " " " " " "	42 "
" 500 " " " " " "	27 "
With 50-foot line of best and smoothest 2½-in. rubber-lined hose .	81 "
" 250 " " " " " " " " " " .	61 "
" 500 " " " " " " " " " " .	46 "

Note how quickly the inferiority of 2-inch hose develops when length much exceeds 50 or 100 feet.

Thus: with 250 feet of 2½-in. linen, effective height of stream = 56 feet.
" 250 " " 2-in. " " " " " " = 20 "

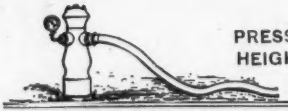
Note also the effect which even ⅛-inch increase in diameter has in reducing friction loss in the hose.

Thus, with 500 feet of smoothest and best rubber-lined hose —

If diam. be exactly 2½ in., effective height of stream will be 39 feet.
If diam. be ⅛th in. larger, " " " " " " 46 "

Three-Inch Hose.

It will be noted that in Table C values are given for fire-hose of 2¾ inches and 3 inches internal diameter. Very little hose of these sizes has yet got into practical use; but the writer has for some months been urging several of the leading hose-makers to introduce such sizes as matters of regular stock, for the reasons stated on page 113, to which reference may be made.



PRESSURE in lbs. per sq. in. indicated at base of play-pipe,
HEIGHT, greatest, as good effective fire stream in moderate wind,
VOLUME in U. S. gallons per minute,
} of Jet obtainable with a given Hydrant Pressure, according to Size, Kind, and Length of Hose used.

TABLE C.

(From experiments of J. R. FREEMAN, 1888.)

TAKE NOTICE.—This "Given Hydrant Pressure" is pressure at the Hydrant, measured as shown in sketch, *while stream is flowing*. The Fire Pump Pressure (or Static Reservoir Pressure) must, meanwhile, be greater than this Hydrant Pressure by an amount equal to friction-loss between Pump and Hydrant. No general statement of the magnitude of this friction-loss can be made, as it depends on length and size of pipe-system, and number of streams being drawn, and may be anywhere from 5 to 40 or more pounds. In a thoroughly first-class Mill Hydrant System, this friction-loss through main pipes and valves ought not to generally exceed 10 or 15 lbs.

		1-Inch Smooth Nozzle.				1⅛-Inch Smooth Nozzle. This is size now generally preferred for outside use.								1¼-Inch Smooth Nozzle.			
Available Hydrant Pressure while Stream is Flowing →		40	60	80	100	40	50	60	70	80	90	100	120	40	60	80	100
50 ft. Ordinary 2-in. Unlined Linen Hose. (Diam. couplings 2-in., but inside diam. hose 2¼-in.)]	Nos. Pressure	**24**	**35**	**47**	**59**	**19**	**23**	**28**	**33**	**37**	**42**	**47**	**56**	**15**	**22**	**29**	**36**
	Height for Fire	42	58	71	78	34	41	49	56	61	67	72	81	28	41	52	61
	Galls. per Min.	144	174	202	226	164	180	199	216	229	244	258	282	181	219	252	282
50 ft. Ordinary 2½-in. Unlined Linen Hose. (Diam. couplings 2½-in., but inside diam. hose 2¾-in.)	Nos. Pressure	**31**	**47**	**63**	**78**	**28**	**35**	**41**	**48**	**55**	**62**	**69**	**83**	**24**	**36**	**47**	**59**
	Height for Fire	52	71	81	88	49	59	66	73	80	84	88	93	44	61	74	84
	Galls. per Min.	164	202	233	261	199	222	241	261	279	296	312	342	230	282	322	359
50 ft. Best 2½-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Diam. couplings 2½-in., inside diam. hose 2⅝-in.)	Nos. Pressure	**35**	**52**	**70**	**87**	**32**	**40**	**48**	**56**	**64**	**73**	**81**	**97**	**29**	**44**	**58**	**73**
	Height for Fire	58	74	85	91	55	65	73	81	85	89	92	98	52	71	83	92
	Galls. per Min.	174	212	246	275	212	238	261	282	301	321	338	370	252	307	358	400
250 ft. Ordinary 2-in. Unlined Linen Hose. (Diam. couplings 2-in., but inside diam. hose 2¼-in.)	Nos. Pressure	**9**	**14**	**19**	**23**	**6**	**8**	**9**	**11**	**13**	**14**	**16**	**19**	**4**	**6**	**9**	**11**
	Height for Fire	17	24	33	40	13	15	17	20	23	25	29	34	9	13	17	21
	Galls. per Min.	90	110	128	141	102	106	16	126	140	147	150	164	97	120	139	155
250 ft. Ordinary 2½-in. Unlined Linen Hose. (Diam. couplings 2½-in., but inside diam. hose 2⅝-in.)	Nos. Pressure	**18**	**28**	**37**	**46**	**14**	**17**	**21**	**24**	**27**	**31**	**34**	**41**	**10**	**15**	**20**	**25**
	Height for Fire	32	49	60	70	25	31	38	42	47	54	58	66	19	28	37	46
	Galls. per Min.	126	155	179	200	147	156	172	184	196	209	220	241	148	181	209	234
250 ft. Inferior 2½-in. Rubber-Lined "Mill Hose." Inside surface rough and uneven. (Inside diam. hose and coupling each exactly 2½-in.)	Nos. Pressure	**20**	**30**	**39**	**49**	**15**	**19**	**22**	**26**	**30**	**34**	**37**	**45**	**11**	**17**	**22**	**28**
	Height for Fire	35	51	63	72	27	34	39	46	52	58	61	70	21	32	41	50
	Galls. per Min.	132	161	184	206	146	164	177	192	206	220	229	252	155	192	219	247
250 ft. Best 2½-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Diam. couplings 2½-in., inside diam. hose 2⅝-in.)	Nos. Pressure	**26**	**39**	**52**	**65**	**21**	**27**	**32**	**37**	**43**	**48**	**53**	**64**	**17**	**25**	**34**	**42**
	Height for Fire	45	63	74	82	38	47	55	61	68	73	78	85	32	46	59	69
	Galls. per Min.	150	184	212	237	172	196	212	229	247	261	274	301	192	234	273	304

Inside surface very smooth. (Diam. couplings 2½-in., inside diam. hose 2¾-in.)	Nos. Pressure	20	30	35	40	21	27	32	37	43	48	53	64	17	25	34	42
	Height for Fire	45	63	74	82	38	47	55	61	68	73	78	85	32	46	59	69
	Galls. per Min.	150	184	212	237	172	196	212	229	247	261	274	301	192	234	273	304

500 ft. Ordinary 2½-in. Unlined Linen Hose. (Diam. coupling 2½-in., but inside diam. hose 2¾-in.)	Nos. Pressure	12	18	24	30	8	11	13	15	17	19	21	25	6	9	12	15
	Height for Fire	21	32	42	51	15	20	23	27	31	34	38	44	13	17	23	28
	Galls. per Min.	101	125	144	161	106	126	140	146	156	164	172	188	120	139	162	181
500 ft. Inferior 2½-in. Rubber-Lined "Mill Hose." **Inside surface rough and uneven.** (Inside diam. hose and coupling each exactly 2½-in.)	Nos. Pressure	13	20	27	33	9	12	14	16	19	21	23	28	7	10	13	17
	Height for Fire	23	35	46	55	17	22	25	29	34	38	41	49	13	19	24	32
	Galls. per Min.	106	132	153	169	116	130	147	150	164	172	180	199	120	148	169	192
500 ft. 2½-in. Rubber-Lined Cotton Hose. **Inside surface very smooth.** (Inside diam. hose and coupling each exactly 2½-in.)	Nos. Pressure	18	26	35	44	13	16	19	22	26	29	32	38	9	14	19	23
	Height for Fire	32	45	58	68	23	29	34	39	46	50	55	63	17	26	35	42
	Galls. per Min.	125	150	174	196	140	150	164	177	192	202	212	232	139	175	204	225
500 ft. Standard 2½-in. Rubber-Lined Cotton Hose. **Inside surface very smooth.** (Diam. coupling 2½-in., but inside diam. hose 2¾-in.)	Nos. Pressure	20	30	39	49	15	19	22	26	30	34	37	45	11	17	22	28
	Height for Fire	35	51	63	72	27	34	39	46	52	58	61	70	21	32	41	50
	Galls. per Min.	132	161	184	206	146	164	177	192	206	220	229	252	155	192	219	247
500 ft. 2¾-in. Rubber-Lined Cotton Hose. **Inside surface very smooth.** (Coupling 2½-in. bore, with taper. Inside diam. hose 2¾-in.)	Nos. Pressure	22	33	44	55	17	21	26	30	34	38	43	51	13	20	26	32
	Height for Fire	38	55	68	76	31	38	46	52	58	63	68	76	24	37	47	56
	Galls. per Min.	138	169	196	218	156	172	192	206	220	232	247	269	169	209	239	265
500 ft. 3-in. Rubber-Lined Cotton Hose. **Inside surface very smooth.** (Coupling 2½-in. bore, with taper. Inside diam. hose 3-in.)	Nos. Pressure	26	39	52	64	21	26	32	37	42	47	53	63	17	25	33	42
	Height for Fire	45	63	74	81	38	46	55	61	67	72	78	85	32	46	57	69
	Galls. per Min.	150	184	212	235	172	192	212	229	244	258	274	298	192	234	270	304
800 ft. Inferior 2½-in. Rubber-Lined "Mill Hose." **Inside surface rough and uneven.** (Inside diam. hose and coupling each exactly 2½-in.)	Nos. Pressure	10	14	19	24	7	8	10	11	13	15	16	19	5	7	9	11
	Height for Fire	18	24	33	42	12	15	18	20	23	27	29	34	9	13	17	21
	Galls. per Min.	93	110	128	144	96	106	119	126	140	146	150	164	105	123	139	155
800 ft. 2½-in. Rubber-Lined Cotton Hose. **Inside surface very smooth.** (Inside diam. hose and coupling each exactly 2½-in.)	Nos. Pressure	13	20	26	33	9	12	14	16	18	21	23	28	7	10	13	16
	Height for Fire	23	35	45	55	17	22	25	29	32	38	41	49	13	19	24	30
	Galls. per Min.	106	132	150	169	116	130	147	150	159	172	180	199	123	148	169	187
800 ft. Standard 2¾-in. Rubber-Lined Cotton Hose. **Inside surface very smooth.** (Diam. coupling 2½-in., but inside diam. hose 2¾-in.)	Nos. Pressure	15	23	31	38	11	14	17	19	22	25	28	33	8	12	16	20
	Height for Fire	26	40	52	62	20	25	31	34	39	44	49	56	15	23	30	37
	Galls. per Min.	114	141	164	181	126	147	156	164	177	188	199	216	132	162	187	209
800 ft. 2¾-in. Rubber-Lined Cotton Hose. **Inside surface very smooth.** (Coupling 2½-in. bore, with taper. Inside diam. hose 2¾-in.)	Nos. Pressure	17	26	35	44	13	16	19	22	26	29	32	39	9	14	19	24
	Height for Fire	30	45	58	68	23	29	34	39	46	50	55	64	18	26	35	44
	Galls. per Min.	121	150	174	196	140	150	164	177	192	202	212	234	139	175	204	230
800 ft. 3-in. Rubber-Lined Cotton Hose. **Inside surface very smooth.** (Coupling 2½-in. bore, with taper. Inside diam. hose 3-in.)	Nos. Pressure	22	32	43	54	17	21	25	29	33	38	42	50	13	19	25	32
	Height for Fire	38	54	67	75	31	38	44	50	56	63	67	75	24	35	46	56
	Galls. per Min.	138	166	193	216	156	172	188	202	216	232	244	266	169	204	234	266

DISCUSSION.

The PRESIDENT. — We have all listened with great interest to Mr. Freeman's paper, and I am certain that he has not given us all the information he has at hand. If any gentleman would like to ask any questions suggested by the paper, I have no doubt Mr. Freeman will be glad to answer them, or if any member wishes to discuss the paper, he can now have an opportunity.

Mr. TIDD. — When Mr. Freeman told us of the discrepancy between the tables of Mr. Ellis and his own experiments, it occurred to me it might be explained in this way: that Mr. Ellis, in getting at the amount of water discharged by his streams, used a meter on the hydrant, — at least he explained to me that was his process of getting at it, — and probably the fifteen to eighteen per cent. the gentleman alludes to represents the obstruction offered by the meter. (Laughter.)

Mr. JONES. — I do not wish to say anything with regard to the scientific portion of Mr. Freeman's paper, but I should like to say a word upon a practical matter which I think should be considered when he speaks of increasing the size of hose to two and three-quarters or to three inches. The old Boston fire department, of which I was a member for a number of years, used only 2-inch leather hose, and the hydrants of the olden time were only two inches at the nozzle outlet. In 1855 the first steam fire-engine came to Boston, from Cincinnati, I think. This steamer used leather hose three inches in diameter. The objection to that was, and it seemed to me as a fireman to be a very serious matter, — you understand that 3-inch leather hose had to be much heavier and stronger than 2-inch, — that it was very inconvenient to handle it full of water on a ladder. That was the objection made at the time. It was, however, quite a jump from two inches up to three inches. It seems to me that 3-inch hose would be a very good thing to use on level ground, when you wanted to supply a hose-tower, or anything of that kind, but I shouldn't want to be one of the men — at my time of life, at any rate — to handle a 3-inch hose on a ladder at the top of a six-story building. (Laughter.)

Mr. FREEMAN. — I am very glad, indeed, Mr. Jones has called attention to this point, and it is a point I had considered in the paper before the American Society of Civil Engineers. If it proves impracticable to take 3-inch hose up a ladder, then by having the hose-couplings entirely interchangeable it would be a very simple thing, having laid a line of 3-inch hose along the ground, to make on to its end with a short line of 2½-inch unjacketed hose for taking up the ladders and into the building. By a little change in the tactics, this could be arranged all right. Very likely I should not myself feel like dragging a 3-inch hose, filled with water, up a high ladder into a building.

Mr. JONES. — I was going to observe, that with two lines of hose with different sizes that might be arranged. But to use any hose larger than 2½-inch on ladders, unless we have other means of handling the hose than human strength, I think would be a disadvantage.

Mr. FREEMAN. — Practice gives a more satisfactory demonstration than theory, and so I may state that the city of Pittsburg now has upward of ten thousand feet of 3-inch hose in active use in its fire department, and that they are well satisfied with the change. They take it up ladders, too.

The PRESIDENT. — This question is very pertinent at the present time, in view of the large fires which have recently occurred. I had hoped to have been

able to give you some definite data in regard to the number of streams played and the amount of water used at the Boston fire of November 28. I have not, as yet, been able to get the matter into presentable shape, but I hope to be able to give it later. I think that the quantity of water used and the number of streams played during this last Boston fire was as large as will often be required. I think we may well continue the discussion, perhaps bringing out some of the points with regard to the quantity of water used at fires, and I would ask Mr. Haskell, of Lynn, if he can give us any information with regard to the water supplied at the Lynn fire.

Mr. HASKELL. — Mr. President and Gentlemen: A few days ago I received an invitation from Mr. Brackett to be present here and give you some information with regard to the amount of water that was used at the Lynn fire.

The source of supply on which we depend is by four artificial basins formed by dams across brooks, and the water of another brook taken direct by gravitation to the pump well, from which it is pumped into a reservoir by a Leavitt engine of 5,000,000 daily capacity, and a Deane engine of 3,000,000 daily capacity. The distributing pipes are a 16-inch main, a 12-inch high-service main direct to the highlands, which can be turned into the low service before it reaches the highlands, and a 12-inch connection with the force main from the reservoir. At the second alarm the high service was turned on, and as soon as it became evident that a large fire was in progress, the 12-inch gate from the force main was opened. At the time of the first alarm the reservoir contained 20,510,872 gallons, and the Leavitt engine was pumping from the brook supply. In addition to our own supply, the Marblehead Water Company furnished water through a 6-inch pipe. The burnt district was environed and intersected with streets supplied with pipes as follows: One 12-inch, five 10-inch, three 8-inch, four 6-inch, eight 4-inch, provided with 35 hydrants.

While it is impossible to give a definite statement of the number of streams drawing at the same time from any section of pipes, the whole number of engines was 19, and the amount of water used from 12 M. until 6 P.M., was 2,908,477; from 6 P.M. till 6 A.M., 5,373,282; from 6 A.M. to 12 M., 2,827,736, — making a total used in 24 hours of 11,109,495 gallons. Deducting the average daily consumption, we have 8,780,285 gallons as the amount used for the first 24 hours of the fire, — 8,780,285.

The large piles of coal and *débris* left burning in the ruins required a continued use of water through hose from the hydrants amounting to 19,376,984 gallons.

One large waste of water came from the services in the burned buildings; as each building was destroyed, the service was added to the draft on the pipes. Some of the largest services were shut off before the buildings fell.

The stand-pipes put in for insurance purposes are a great source of waste, as the pipes are large, and cannot be shut off as long as they are liable to save the buildings, when in many cases it would be impossible to close the gate. During the progress of the fire no bursts occurred in the pipes, and nothing occurred to interfere with the circulation of the water. (Applause.)

Mr. SHEDD. — I was much interested in Mr. Freeman's paper, and I think he has given us a great deal of information on the subject of water supply for fire use. I think, so far as my observations and experiments have extended, they would harmonize entirely with the statements which he has made; and the sug-

gestions which he makes I consider are very valuable indeed. It is a matter of very great consequence to those who own property and to the fire-insurance companies that an ample supply of water should always be ready for use at a fire. The pipes for our modern systems of distribution I think are generally very well devised for fire protection. It costs about half the whole cost of a water system to make it suitable for furnishing water at fires, and very often the revenue does not equal the legitimate cost for that purpose. But a great many of the distribution systems are in an unfortunate condition. A good many lines of pipes across a system of distribution, from the source of supply to nearly the end of the district to be protected, would in many instances be very valuable; and I hope the result of discussions of this sort will be to put a good many distributions into a better condition to be suitable for use in putting out large fires than they are in now.

Mr. HAWES. — I would like to ask Mr. Haskell whether there was water enough at the Lynn fire, or whether they were troubled with lack of supply?

Mr. HASKELL. — I do not think there ever was a large fire of that sort when any one would say there was water enough, even if enough was used to flood the district ten or fifteen feet deep.

Mr. HAWES. — It strikes me the idea which was suggested of using two sizes of hose at a fire is a little impracticable. At most fires I have attended the firemen are apt to be in a hurry, and they wouldn't be likely to stop at the foot of a ladder and hunt around after a 2½-inch hose to couple on. They would go right up with it, I guess, no matter what size the hose was. I think they would take it up if it was five inches, and they had to put a man on every round of the ladder. (Laughter and applause.) I never saw firemen at a fire but once when there wasn't any hurry, and that was down at Nantucket. There happened to be sixteen of us down there one day who belonged to Cataract No. 3, of Fall River, when there was an alarm of fire, and when the machine went by we saw it was Cataract No. 3, and so we all took hold and went to the fire. (Laughter.) When we got there we found it was a barn. A ladder was put up, and one of our men took an axe, when the owner of the barn rushed up and said: "Don't, don't cut that door! Wait a minute and I will get a screw-driver, and you can take the hinges off." (Laughter.) This is the only fire I ever went to when they were not in a hurry.

Mr. HASKELL. — Mr. Hawes' remarks lead me to think that perhaps the firemen at Lynn had ample time in those cases Mr. Freeman spoke of, where they had run 2,000 feet of hose. They must have gone by a number of hydrants before they attached their hose, for I think there was no place where they could have gone 500 feet without finding a hydrant.

Mr. WINSLOW. — I would like to ask Mr. Freeman in what way this friction loss in hose was determined; in other words, how the hose was laid, — whether it was laid straight, or laid as it naturally would be by the fire department. The reason why I ask this question is that Ellis' book is considered as authority by the firemen in my place, and you say he is in error about eighteen per cent. I don't know in his case whether the hose was laid as firemen would lay it, or whether it was laid for the experiment, and that is the reason I ask you how yours was laid.

Mr. FREEMAN. — The point in which I referred to Ellis as being eighteen per

cent. in error was in relation to the number of gallons discharged per minute, not in relation to the friction loss in the hose. In determining the amount of pressure lost by friction in the hose, I experimented with the hose straight, and also with the hose crooked, just as the firemen would lay it, and found that between laying it straight and laying it in a serpentine form there was a difference of about six per cent. in the amount of pressure lost by friction.

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